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VOL. 8 SEPTEMBER, 1921 NO. 5

A RESERVOIR VERSUS ADDITIONAL PUMPAGE CAPACITY FOR SUPPLYING PEAK DEMANDS[1]

By L. A. Quayle[2]

In the planning of a new waterworks project of comparatively large size, or the enlarging of one that is in service, it is necessary to determine how much of the hourly, daily, or monthly peak demands shall be taken by one or more equalizing or distributing reservoirs and how much by pumping engines in addition to those required to supply the average quantity of water consumed over a given period. It is assumed that the topography of the area to be supplied is such that reservoir sites are available.

In villages or cities of comparatively small size, the capacities of stand pipes or reservoirs are largely determined by the fire protection requirements, rather than the considerations discussed herein. As the size of the city increases the relative capacity of the reservoir required for fire protection becomes less and less, until in a city the size of Cleveland the quantity of water used for a large fire is such a small part of the total daily consumption, that it has no appreciable effect on the hourly rate of pumpage or the daily quantity pumped.

[1] Presented at the Cleveland Convention, June 7, 1921. Discussion of this paper is desired and should be sent to the Editor.

[2] Chief Mechanical Engineer, Cleveland Water Department, Cleveland, Ohio.

In this discussion we are referring only to the equalizing or distributing types of reservoirs. The equalizing reservoir being one that is connected to the pumping station through the distribution system, and the distributing reservoir being one which receives all the water from the pumping station before it flows by gravity into the distribution system. Impounding or storage reservoirs, except where they are elevated sufficiently above a city to supply the water by gravity, do not act as equalizing reservoirs for the distribution system and are therefore not of interest in so far as this particular problem is concerned.

We are assuming throughout this discussion that the equalizing or distributing reservoir is elevated sufficiently above the highest buildings being supplied and that the distribution mains are of sufficient size, to allow the water level in the reservoir to fluctuate over a wide range without appreciably affecting the distribution pressure.

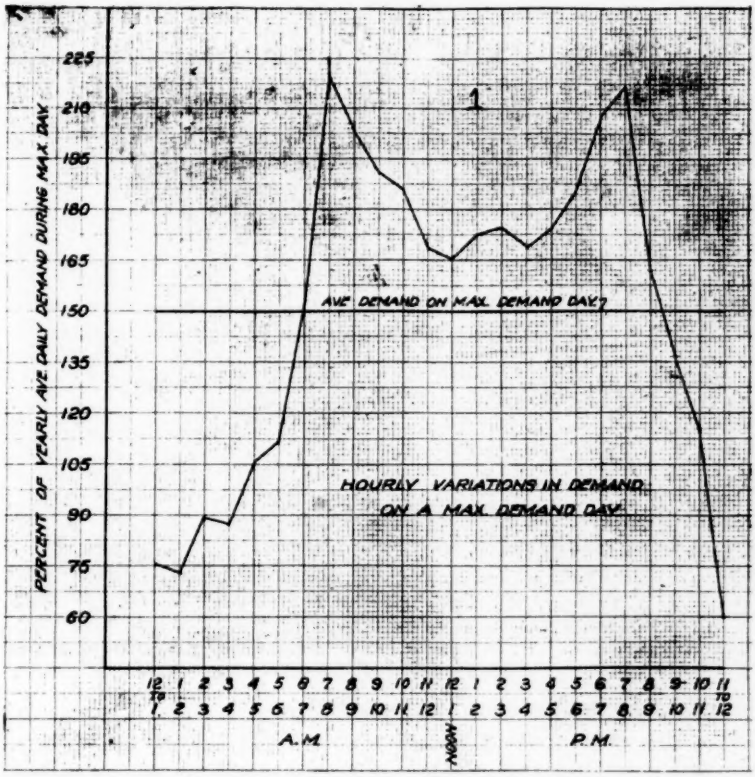
While no two cities have exactly the same ratio of hourly, daily, and monthly demands to meet, or have just the same ratio of intake, pumping station and filter plant cost, to reservoir cost, that hold good for Cleveland, we believe that our conditions are sufficiently representative of those which obtain in a large number of cities, that the analysis we have made of additional pumpage capacity versus reservoir capacity will be useful as a guide in the design of waterworks systems when the particular local conditions of the waterworks being planned are given due consideration.

In order to determine for what variation in demand for water a reservoir should be planned, we have studied the department's pumpage and water consumption records back to the year of 1910, and we have assumed that the maximum variation in demand a reservoir will be required to meet, corresponds to the maximum variation found on the maximum day, week, or month of the maximum year during the ten year period.

In order to simplify the computations, we have based our pumpage demand and cost curves on an average yearly water consumption of 100,000,000 gallons per day which is referred to as 100 per cent capacity on the various curves.

Curve 1 shows graphically the hourly variation in demand on a maximum demand day. The quantity of water pumped on a maximum demand day would be 150,000,000 gallons, and the rate of demand for the period of an hour would vary from 220,000,000 gallons per day from 7:00 to 8:00 a.m. to 60,000,000 gallons per day

from 11:00 p.m. to midnight. The maximum momentary rate of pumpage would be approximately 225,000,000 gallons per day for a few minutes between 7:00 and 8:00 a.m. If a pumping station furnished water at a uniform rate of 150,000,000 gallons per day, a reservoir of 20,600,000 gallons capacity would take care of all the hourly and momentary fluctuations shown on the curve. If



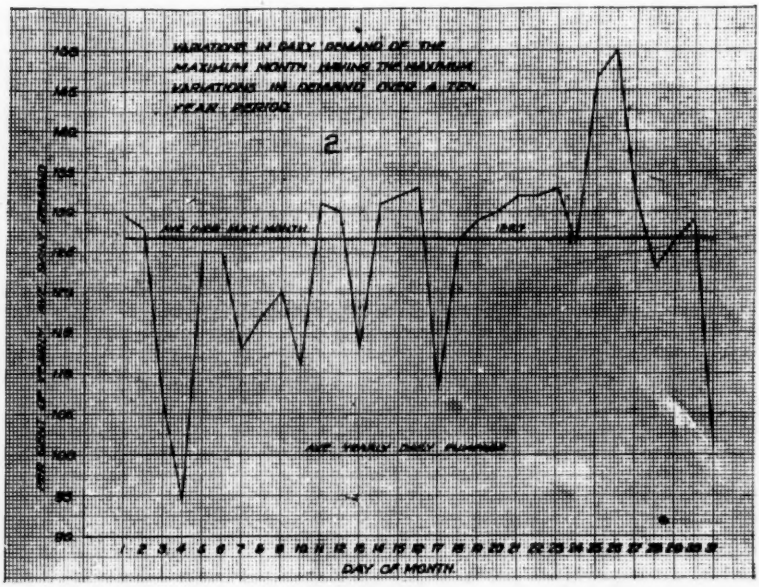
CURVE 1

no reservoir were used a pumpage capacity of 225,000,000 gallons per day would be required.

Curve 2 shows the variation in daily demand of the month having the maximum variation in the maximum year of the ten year period. The average pumpage for the maximum month would be 126,700,000 gallons per day. The maximum sustained pumpage above the average monthly pumpage would be for the 8-day period

from the 20th to the 27th inclusive, which would average 135,200,000 gallons per day. A reservoir large enough to take care of the 8-day sustained demand and the two days of highest pumpage, the 25th and 26th, on which days the demand was 147,000,000 and 150,000,000 gallons per day respectively, would more than take care of all other variations in demand during that month, or any other month of the ten year period.

Curve 3 shows graphically the monthly variation in pumpage in the year having the greatest variation over the ten year period.


VARIATIONS IN DAILY DEMAND OF THE MAXIMUM MONTH HAVING THE MAXIMUM VARIATIONS IN DEMAND OVER A TEN YEAR PERIOD
2
DAY OF MONTH

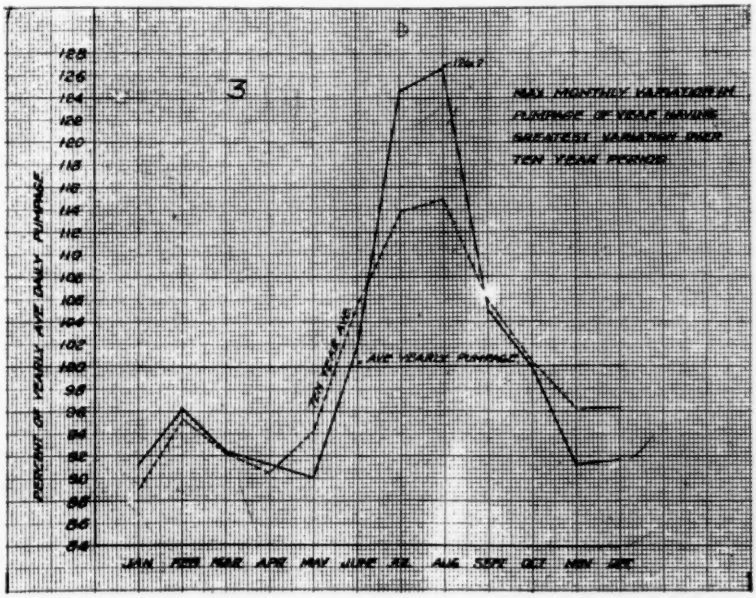
Curve 2

You will note that the average pumpage of the maximum month would be 126,700,000 gallons per day as was also shown on curve 2. If the pumping station should work at a uniform rate of 100,000,000 gallons per day throughout the entire year, a reservoir having a capacity of 1,800,000,000 gallons would be required to take care of all variations.

Curve 4 shows graphically the various capacities of the reservoir required to take care of all variations in demand throughout the year with pumping stations of varying capacity, it being assumed as be-

fore stated, that 100 per cent demand corresponds to an average yearly demand of 100,000,000 gallons per day.

A study of curve 1 showed that a 20,600,000 gallon reservoir would take care of hourly fluctuations on a maximum day of 150,000,000 gallons per day demand, with a pumpage of 150,000,000 gallons. With a station of larger capacity the size of reservoir decreases as shown on the curve. With a pumping station of less than 150,000,000 gallons per day, the two days of 147,000,000 and

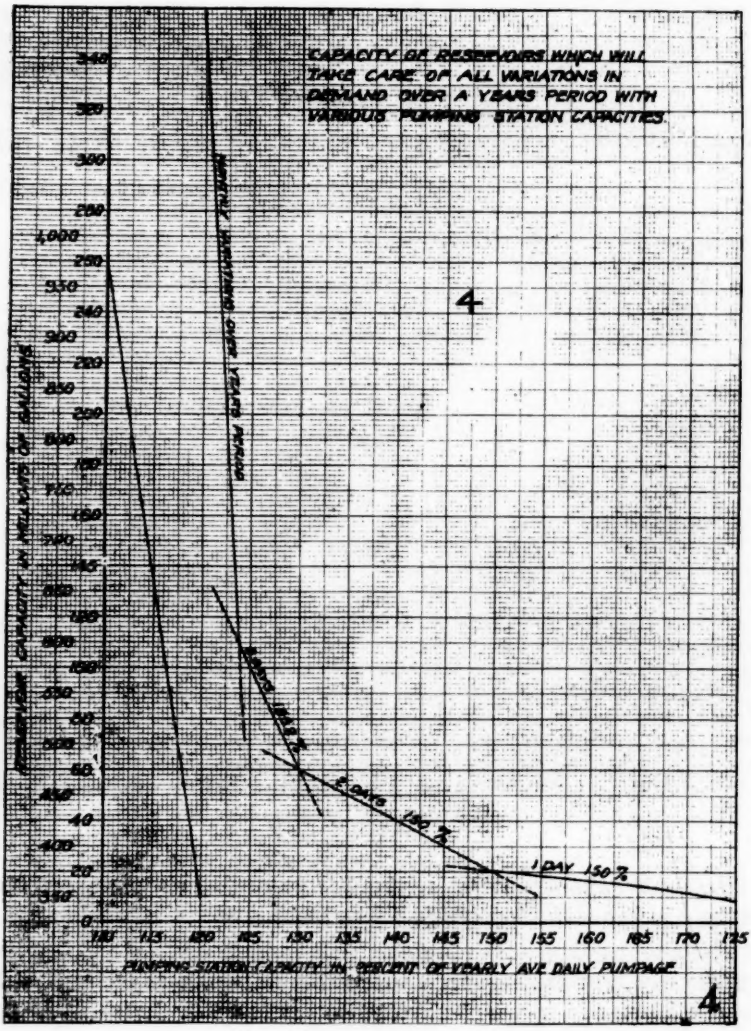

3
MAX MONTHLY VARIATION IN PUMPAGE OF YEAR HAVING GREATEST VARIATION DUR TEN YEAR PERIOD
AVE YEARLY PUMPAGE
PERCENT OF YEARLY AVE DAILY PUMPAGE
JAN FEB MAR APR MAY JUNE JUL AUG SEPT OCT NOV DEC

CURVE 3

150,000,000 gallons per day (to simplify, say two days of 150,000,000 gallons per day demand) become the factor which determines the size of the reservoir up to the point where the 8 days of 135,200,000 gallons per day pumpage require greater reservoir capacity, which corresponds to a station of 130,000,000 gallons per day capacity.

The 8-day demand line crosses the line showing the reservoir capacity necessary to take care of the monthly fluctuations over a year's period, at a pumping station capacity of approximately 124,000,000 gallons per day.

By combining these lines into one curve we can determine from the curve the size of the reservoir required to take care of any de-


CAPACITY OF RESERVOIRS WHICH WILL TAKE CARE OF ALL VARIATIONS IN DEMAND OVER A YEARS PERIOD WITH VARIOUS PUMPING STATION CAPACITIES.
4
MONTHLY MAXIMUM OVER YEARS PERIOD
WEEKS MAX %
5 DAYS 130 %
1 DAY 150 %
110 115 120 125 130 135 140 145 150 155 160 165 170 175
PUMPING STATION CAPACITY IN PERCENT OF YEARLY AVE DAILY PUMPAGE
4

Curve 4

mands which will be made upon it over a year's period, with different capacities of pumping stations supplying the average demand.

Having determined from the curve the combination of sizes of pumping station and reservoir required to take care of all fluctuations in demand, we must next find out what the first cost of the various combinations is, in order to determine the most economical combination to construct, in so far as first cost is concerned.

The costs of the cribs, tunnels, pumping stations, reservoirs, etc., used are based on the average cost of Kirtland and Division tunnel systems and pumping stations, Fairmount, Kinsman and Warrensville reservoirs, and Division Avenue filtration plant. All capital operation and maintenance charges are based on pre-war costs. Since we are interested primarily in the ratio of the cost of one type of construction to another and not in the absolute cost, we believe the use of the comparatively stable pre-war prices is preferable to trying to change these costs to the present unstable basis.

We have tabulated below the approximate costs of our various waterworks projects, the average cost per million gallons of capacity for each, and the assumed life of the property upon which we based the annual fixed charges.

Cost of cribs, tunnels, aqueducts and screen wells

	KIRTLAND SYSTEM	DIVISION SYSTEM
Type of crib	Permanent steel	Submerged
Diameter of tunnel system—feet	9	10, 7 and 5
Length of each sized tunnel—feet	26,000	16,100—9,200
Total cost of intake systems	$1,500,000	$2,530,000
Capacity of tunnel system—m. g. p. d.	175	175
Cost per million gallons per day of capacity	$8,550	$14,450
Average cost of cribs, tunnels, aqueducts and screen wells for Kirtland and Division systems per million gallons of daily capacity	$11,500	

Assumed life of cribs, tunnels, aqueducts and screen wells—100 years.

Cost of waterworks land. The cost of land used for waterworks purposes has not been included in this comparison as the yearly appreciation of Cleveland waterworks land more than covers the yearly cost of the bonds which are required for its purchase.

Pumping station costs

	KIRTLAND	DIVISION
Buildings (pumping engine and boiler house).	$600,000	$405,000
Triple expansion pumping engines	786,000	805,000
Boilers, piping and miscellaneous equipment.	224,000	190,000
Total pumping station cost	$1,600,000	$1,404,000
Ultimate capacity of pumping stations—m. g. p. d.	165	165
Cost per million gallons of capacity	$9,700	$8,500
Average cost of both stations per million gallons of capacity	$9,100	

Assumed life of complete pumping stations—30 years

Filtration plant

Cost of Division Avenue filtration plant having a rated capacity of 150,000,000 gallons per day	$2,250,000
Cost per million gallons of capacity	$15,000
Assumed life of filtration plant	50 years
Cost of low-lift building, pumps and proportional cost of boilers and miscellaneous equipment	$297,000
Cost per million gallons capacity	$1,800
Assumed life of complete low-lift pumping station	30 years

Distribution system cost. We have assumed that the cost of the distribution system would be the same for direct as for reservoir pumpage, and have not included its cost in any data compiled herein.

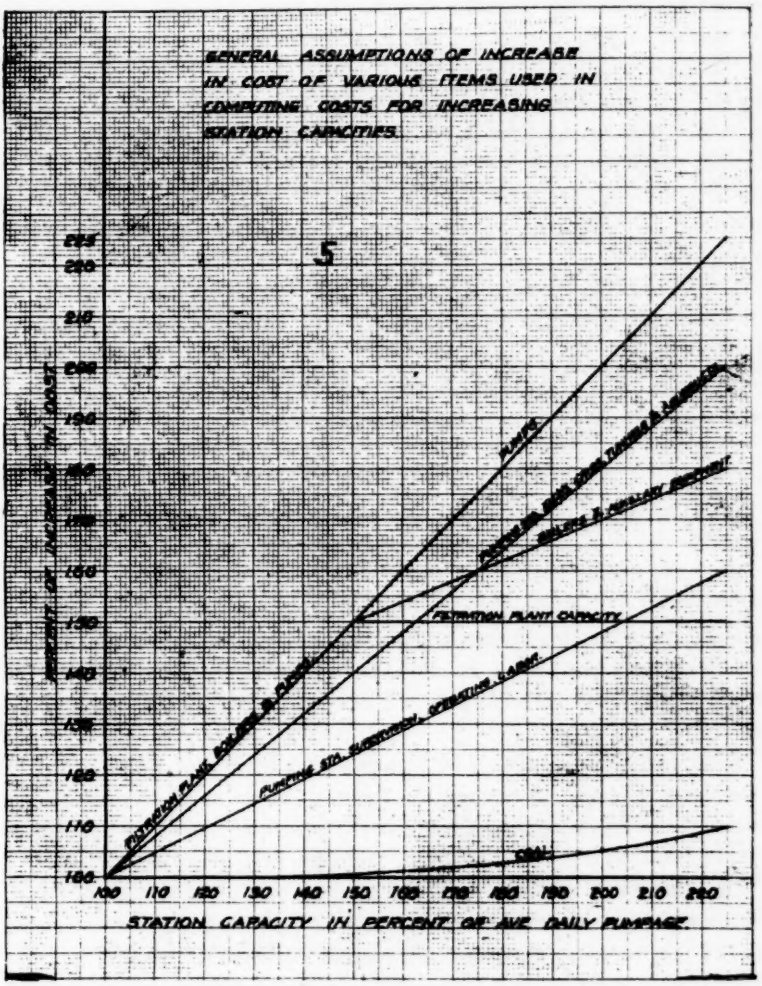
Reservoir costs

	FAIRMOUNT	KINSMAN	WARRENSVILLE
Capacity of reservoirs—gallons	80,500,000	35,600,000	22,300,000
Year completed	1885	1885	1914
Cost of reservoir	$404,400	$159,400	$137,600
Cost per million gallons	$5,300	$4,475	$6,170
Average cost of three reservoirs per million gallons of capacity	$5,315		

Assumed life of reservoirs—100 years

In determining the capital, operation, and maintenance costs of the tunnel systems, pumping stations, filtration plants and res-

ervoirs of proper capacity to take care of an average yearly demand of 100,000,000 gallons per day with pumping stations of various maximum capacities, a large number of assumptions had to be made


GENERAL ASSUMPTIONS OF INCREASE IN COST OF VARIOUS ITEMS USED IN COMPUTING COSTS FOR INCREASING STATION CAPACITIES.
5
PERCENT OF INCREASE IN COST
100 110 120 130 140 150 160 170 180 190 200 210 220
STATION CAPACITY IN PERCENT OF AVE. DAILY PUMPAGE.
PUMPS
FILTRATION PLANT CAPACITY
COAL

CURVE 5

and those having the greatest influence on this subject are shown diagrammatically in curve 5.

You will note from the curve labeled "Pumping Station Buildings, Cribs, Tunnels and Aqueducts" that we have increased the cost

80 per cent for double the capacity. This is due to the fact that the unit costs of the tunnel systems and pumping stations would be somewhat less for the larger capacities, and the boiler house building would be relatively smaller due to the fact that the boilers could be run at higher ratings for short periods and the tunnel size could be relatively smaller for peak demands than for steady demands, as the friction loss could be somewhat greater for a peak demand of a given rate than for a steady demand of the same rate. The tunnel capacity does not exceed 150,000,000 gallons per day when used in connection with a filter plant, as the clear water basin is assumed to take care of the hourly fluctuations of filtered water pumpage.

The pumping station, boiler and miscellaneous equipment costs curve shows that the costs vary directly with the station capacity up to 150,000,000 gallons per day and that they increase 30 per cent more for a 225,000,000 gallon capacity station as compared with the 150,000,000 gallon station.

You will note from the curve that the filter plant capacity does not exceed 150,000,000 gallons as the clear water basin is assumed to take care of all hourly fluctuations throughout a maximum demand day.

We have made no increase in the cost of coal for the plants operating up to 130 per cent capacity, but have assumed that the coal cost would be gradually increased until it becomes 10 per cent higher for direct pumpage at a 225,000,000 gallon peak than for a station which would only have to pump a maximum of 130,000,000 gallons per day.

With the direct system of pumpage, pumps and boilers run at a lower load factor, as the station must be ready at all times for large fluctuations in demands which would result in a somewhat lower over-all station duty and resulting increase in coal consumption.

The pumping station supervision and operation is assumed to increase 60 per cent for an increase in pumping station capacity of 125 per cent. The cost of tunnel operation, which includes cribkeeper's salaries, etc., remains the same irrespective of the size of the tunnel.

The open reservoir unit costs have been assumed to vary from $5500 per million gallons for a 10,000,000 gallon reservoir to $5000 per million gallons for a 200,000,000 gallon reservoir. The cost of the covered reservoirs is assumed to be double that of the open reservoirs.

Reservoir operation costs consisting principally of keeper's and gardener's salaries vary from $115 per million gallons for a 10,000,000 gallon reservoir to $15 for a reservoir of 200,000,000 gallons capacity or over.

Filter plant supervision, labor, chemicals and supplies are assumed to be the same over a year's period, whether the plant operates steadily at a 100,000,000 gallon rate or filters up to rates of 150,000,000 gallons per day, although with a plant taking care of a varying demand the chemical costs, for instance, might be slightly higher.

By the use of curves 4 and 5 and the tabulated costs of the pumping stations, tunnel systems, etc., given above, we have determined the combined first cost of various sizes of tunnels, pumping stations, filter plants and reservoirs required to take care of all variations in demand throughout the year. These costs are shown graphically on diagram 6.

Curve A represents the conditions of operation for Kirtland Pumping Station from its completion in 1904 to the present time.

Curve B represents the conditions of operation of the new Division Avenue Pumping Station and filter plant since its completion in 1917 to the present time.

Curve C would represent the conditions at Kirtland if it were a centrifugally equipped pumping station, after Baldwin reservoir is completed.

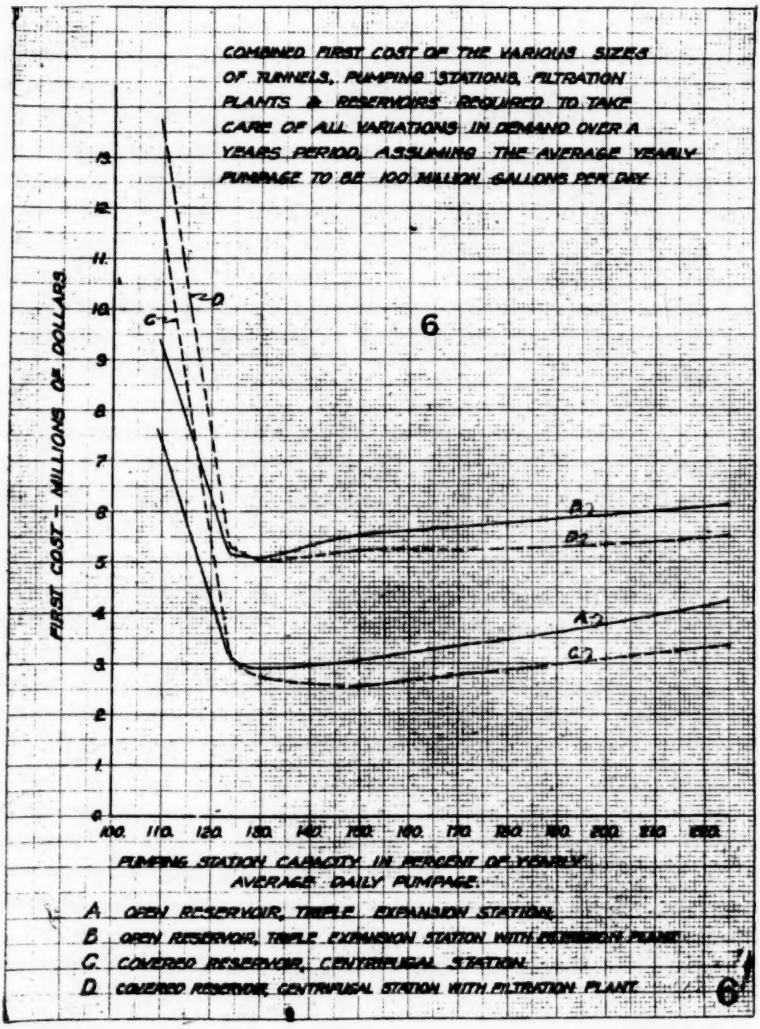
Curve D would represent the conditions of operation of Kirtland and Division pumping stations if they were equipped with centrifugal pumps and after Baldwin reservoir and filtration plant are completed.

The present tendencies point to a gradual change in many localities from triple expansion pumping stations and open reservoirs, to steam turbine driven centrifugal pumping stations and covered reservoirs, and curves A, B, C, and D, show the comparative costs of these different types of construction.

The capital charges for conditions A, B, and D, are all approximately a minimum for a 130,000,000 gallon capacity pumping station and a 60,000,000 gallon capacity reservoir, and for the centrifugal station, filter plant and covered reservoir combination of curve D, the minimum cost would be for a 150,000,000 gallon capacity pumping station and a 20,600,000 gallon reservoir.

These curves also show that it would be just as economical from the standpoint of first cost to either build pumping stations of

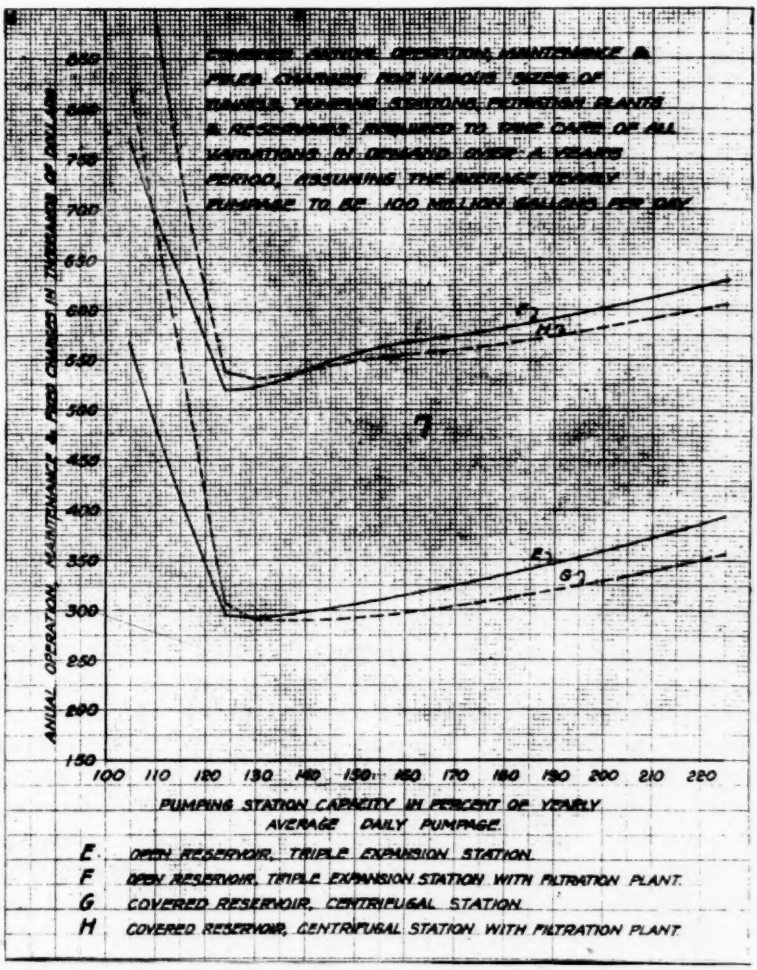
225,000,000 gallons capacity for direct pumpage or open reservoirs of approximately 340 million gallons capacity for conditions A and


COMBINED FIRST COST OF THE VARIOUS SIZES OF TUNNELS, PUMPING STATIONS, FILTRATION PLANTS & RESERVOIRS REQUIRED TO TAKE CARE OF ALL VARIATIONS IN DEMAND OVER A YEARS PERIOD, ASSUMING THE AVERAGE YEARLY PUMPAGE TO BE 100 MILLION GALLONS PER DAY.
FIRST COST - MILLIONS OF DOLLARS.
6
C
D
B2
B1
A2
C2
100. 110. 120. 130. 140. 150. 160. 170. 180. 190. 200. 210. 220.
PUMPING STATION CAPACITY IN PERCENT OF YEARLY AVERAGE DAILY PUMPAGE.
A. OPEN RESERVOIR, TRIPLE EXPANSION STATION.
B. OPEN RESERVOIR, TRIPLE EXPANSION STATION WITH FILTRATION PLANT.
C. COVERED RESERVOIR, CENTRIFUGAL STATION.
D. COVERED RESERVOIR, CENTRIFUGAL STATION WITH FILTRATION PLANT.
6

CURVE 6

B. and closed reservoirs of approximately 240,000,000 gallons capacity for conditions C and D with the corresponding sizes of pumping stations.

In the construction or reconstruction of a waterworks, the first cost is of relatively less importance than the annual costs made up of operation, maintenance and fixed charges.


ANNUAL OPERATION, MAINTENANCE & FIXED CHARGES IN THOUSANDS OF DOLLARS
650
600
550
500
450
400
350
300
250
200
150
100 110 120 130 140 150 160 170 180 190 200 210 220
PUMPING STATION CAPACITY IN PERCENT OF YEARLY AVERAGE DAILY PUMPAGE
E OPEN RESERVOIR, TRIPLE EXPANSION STATION
F OPEN RESERVOIR, TRIPLE EXPANSION STATION WITH FILTRATION PLANT
G COVERED RESERVOIR, CENTRIFUGAL STATION
H COVERED RESERVOIR, CENTRIFUGAL STATION WITH FILTRATION PLANT

CURVE 7

By the use of curves 4 and 5 and the assumptions given below, we have drawn curves E, F, G, and H, diagram 7, to show the combined annual operation, maintenance and fixed charges for various

sizes of tunnels, pumping stations, filtration plants and reservoirs required to take care of all variations in demand over a year's period, assuming the average yearly pumpage to be 100,000,000 gallons per day.

In computing the annual fixed charges we have assumed the life of the various waterworks properties to be a certain number of years, and have added to the yearly maintenance cost the annual payment required to retire a serial bond in the amount of the cost of the property, the bond having the same life as the waterworks property being considered. In other words, the money borrowed to pay for the construction of the tunnels, pumping stations, filtration plants and reservoirs, will have been paid back by the time they have become obsolete or worn out.

In computing maintenance, we have determined from our records what per cent our maintenance costs have averaged over a long period of years, and have applied that percentage to the costs of the various waterworks properties.

The general method of varying the operating costs for the increasing sizes of tunnels, pumping stations, filtration plants, and reservoirs, has been indicated above in the description of curve 5.

You will note that curves E and G are a minimum for 130,000,000 and 140,000,000 gallons per day respectively, while curves F and H reach their minimum points at 124,000,000 and 130,000,000 gallons per day respectively. The difference between these points in both cases is due to the fact that the cost of operation and maintenance of the triple expansion station with an open reservoir is relatively greater than for the centrifugally operated station with a covered reservoir and therefore the pumping capacity of the triple expansion station would be smaller than the centrifugal for the same annual costs. It will also be observed for curves F and H, which include a filtration plant, that the difference in pumping station capacity is 6,000,000, whereas for curves E and G, which do not include a filtration plant, the difference in pumping station capacity is 10,000,000. This is explained by the fact that the annual cost of the filtration plant is a relatively large percent of the entire annual waterworks cost and therefore the difference in annual cost between the triple expansion open reservoir combination and the centrifugal covered reservoir combination is relatively less.

It is interesting to note that the annual operating costs would be the same for direct pumpage as for pumping station and reservoirs having capacities as follows:

		Gallons
Condition E	Pumping station capacity	116,300,000
	Reservoir capacity	570,000,000
Condition F	Pumping station capacity	115,400,000
	Reservoir capacity	625,000,000
Condition G	Pumping station capacity	122,000,000
	Reservoir capacity	220,000,000
Condition H	Pumping station capacity	120,800,000
	Reservoir capacity	295,000,000

We would like to add here, as a matter of interest, that we have plotted curves using entirely different assumptions than were used in the plotting of diagrams 5, 6 and 7, and the general characteristics of the first cost and annual cost curves corresponding to diagrams 6 and 7 were not materially changed, which would indicate that the curves submitted cover a rather broad field in a general way. We have not included the additional curves or a discussion of them, as we did not wish to burden this paper with the further data.

In order to simplify the problem as much as possible, we have not included in our costs the additional investment which would be required to provide a reserve capacity for either pumping stations or reservoirs. We find, however, that our disregarding this item does not appreciably affect the data contained herein.

It is evident that the reservoir of the most economical combination would be required to change its contents 60,000,000 gallons, and a reservoir which would change 60,000,000 gallons in capacity would presumably be one of at least 80,000,000 gallons in actual total capacity, so that a reasonable reserve would be available for emergencies at all times.

The cost of this additional capacity would be approximately the same as the cost of the necessary reserve pump capacity which would be required at the pumping station.

Few waterworks are planned without provisions being made for continuous growth at a greater or less rate. The doubling of a size of a pumping station originally designed for such an extension could be done quite economically. However, another basin could be added to a reservoir which had proper provision made for it in the original construction with equal facility, so that in the matter of providing for future growth the pumping station and reservoir are not greatly different.

In conclusion, we believe that a study of the curves and data discussed herein will give one a fair idea of the relative merits of reservoirs as compared with additional pumping capacity for taking care of the various fluctuations in demand that a waterworks system is called upon to meet. The inherent ease with which a reservoir can meet large and rapid fluctuations in demand, its great value as an emergency reserve, as well as its economy in annual cost, make possible its great value for waterworks service.

For conditions of demand similar to those discussed, the use of the direct system of pumpage would be a questionable economy even though reservoir sites were not available, as a study of the curves indicate that steel or concrete tower tanks of several times the unit costs of reservoirs, could be constructed to take care of hourly fluctuations with considerable resulting economy.

PRESIDENTIAL ADDRESS[1]

By Beekman Cox Little[2]

Through long established custom this Association has in a way made its president's address resemble a valedictory, inasmuch as he relinquishes his office very soon after its delivery.

There is something soothing to the present speaker to know that according to our constitution his term of office *does* expire definitely at the close of this convention, and is not dependent on the quality of his speech; for should this latter condition prevail, he fears his retirement would be forced by popular vote in about fifteen minutes.

It speaks indeed well for the patience and endurance of our members that for forty years—with but one exception—this Association has survived the annual infliction of a formal President's Address. Fortunately however the reputation of the Association does not rest entirely upon this record in its long history. There are many other happenings to which we can point with more pride and with happier recollections.

My active connection with the Association does not go back to its beginnings, nor does my memory, but its growth is a matter of record, and graphically its progress—activity and influence for good—would be represented by a line constantly curving upwards.

There should be no fear of its becoming too large or unwieldy if we remember—as Mr. Davis explained to us last year—that our real scope is to act, in a very broad sense as a great central organization embracing all the water works plants in the county, gathering in from them vast funds of information which it may in turn index, tabulate and re-issue as an invaluable aid and guide to the various Sections and individual communities as the need for it appears.

The planning, constructing and maintaining of our water works now present so many different problems that our position as set forth by our claims, is weak unless we have among us men fitted

[1] Presented at the Cleveland Convention, June 8, 1921.

[2] Retiring President, American Water Works Association; Superintendent, Bureau of Water, Rochester, N. Y.

by experience and by education to help with any difficulty which arises.

Our American Water Works Association would fail—and would deserve to fail, for it would belie its name and aim—if it did not welcome and do all in its power to attract and hold in its membership all of the water works superintendents and managers—even to those of the very smallest plants. On the other hand it must take no step which might to the slightest degree tend to repel or exclude the technical man in the engineering or other professions who may be active and interested in any phase of water supply.

It would be idle to speculate upon, and I believe impossible to ascertain, which of those two classes, the civil engineer or the superintendent, is most important to the life of this organization and I think a vote of no by a large majority would result on a resolution favoring either.

Each of us must know and should base his actions always in this Association on the predication that most decidedly we need all kinds of water works men, and that all kinds need us.

With men of so many minds, we may have differences of opinions, but concerning the management of the affairs of our Association I find these differences merely cover methods or plans of reaching the same conclusion.

The welfare of the Association is the one aim striven for and there can be no fundamental danger to it in our arguments and discussions when all have honestly its best interests at heart. Ever since my application for membership was favorably acted upon—some eighteen years ago—my admiration for the Association has kept increasing, but during the past year when my official duties caused greater opportunities for knowing much better its personnel and its workings, my enthusiasm and pride in it have surpassed the accumulation of all the other years put together.

Your officers and trustees seem to have a real affection for the Association and give to it uncomplainingly many hours of valued service. You may rest assured that their decisions are reached only after careful deliberation and with not the slightest ulterior motive. They accept in good faith the trust which you have put upon them and desire only to render a proper account of their stewardship. This good character thus given by me to your officers with whom I have come in contact, naturally reflects on all of the members by whom they were chosen, and from whose ranks they have come.

It seems to me that as a class, there is none other which represents so much of usefulness, hard work, earnestness of purpose, common sense and knowledge of—and devotion to—his calling, as does the water works man; and by the water works man I mean the composite figure which makes up our Association—from the superintendent of the village system to the chief engineer or general manager of our large metropolitan districts; from the weather beaten untiring foreman who seems to care for his meters, mains and hydrants as if they were his own, to the expert on filtration or purification methods who spends most of his waking hours in keeping the dangerous bacillus in its proper place and condition. Mayhap, the individual in each of these extremes does emphasize the importance of his work and minimize the difficulties which the other encounters, but they all seem to cooperare and *do* understand that *together* they are working for just one splendid result, that is to make our public water supplies as reliable, as pure and as efficient as is humanly possible.

We of course know the burden of responsibility which rests upon us, but our employers—the Public—long accustomed to a most satisfactory service, which they have always obtained from this one of the great public utilities—seem to realize neither the scope of our success nor the extent of the ensuing calamity should we fail.

Years ago, and by that I mean—back before this American Water Works Association was formed—it might have been possible for any business man of good average ability to take over the management of a water works system and get away with it, according to the light of those days, but today, that manager would carry on but a short time unless he had at his command, the advice and help of such men, for example, as are gathered at this convention.

The superintendent of water works in these days has to deal not alone with the general problems connected with the construction and operation of his plant, but also with those of sanitation, chemistry, forestry, bacteriology, electricity and finance—just to mention a few. He must acquaint himself with the laws pertaining to public utilities and be conversant with state and national health regulations which may have a bearing on the operation of his plant. He should be a diplomat, capable of pleading his cause with skill and force. It goes without saying that by virtue of his office he generally has to be a politician, but greatly to his credit be it said that he almost invariably is that type of politician much to be emulated, i.e., one who attracts adherents to his party by the way he attends to

the public business which has been intrusted to him. The Public finds him generally as dependable as the commodity he serves. The average citizen, always able to obtain his needed supply of water with the greatest ease and at a wonderfully low cost compared with other necessaries of life, apparently does not attribute to the man back of the pumps or reservoirs, any possessions beyond a wrench and suit of overalls. This attitude is due to the fact that Mr. Taxpayer hardly ever is told anything different.

Through a fear of praising and advertising our own achievements we are too prone to let him go on in the old belief that water is or at least ought to be as free as air and as easy to obtain.

There is scheduled for this Convention, a paper on Water Works Publicity, and without knowing the author's argument, or desiring to steal his thunder, I would earnestly urge this Association to seriously consider the advisability of a dignified campaign of advertising.

The water works man now fights his battles alone, with little encouragement and wins them with no applause.

The successful operation of his plant is seemingly taken for granted and only in the case of a rare failure or accident is he brought into the limelight, and then generally to be blamed.

There are, though but few know it, many great men in the water works profession. Some of them are facing me now and the names of many others appear on the roster of our organization. They are great because they are successfully conducting and directing the most important of our public utilities and the mark of their greatness lies in the fact that they are performing their work faithfully, efficiently, and quietly, content in the feeling that their work is well done, seeking no praise and fearing no criticism.

At some future time the real value, to the country, of the water works man, is bound to be recognized and then he will become famous as well as great. We should do all that we can to hasten this time, not through selfish motives, but because the fame of the individual necessarily attracts attention to the work in which he is engaged.

With a better knowledge of our water supplies and their needs instilled into the citizens of our communities, a greater enthusiasm will be aroused. It will then become easier to obtain backing in the many projects for extensions and improvements which we know should go on and which so often are too long delayed. A well

defined policy of educating and interesting the Public would I believe easily bring about this much desired end. We shall be told at a later session of this Convention how the scheme has worked splendidly in individual cases, and it should be successful on a much wider scale if entered into and carried on by us as an Association project.

There are many marvellous steps and paths which a drop of water takes from the distant lake, reservoir or deep well, before it emerges from the faucet in the home or factory. They may all seem prosaic enough to us, but these wonderfully simple things might appear to others in the telling, simply wonderful and in all truth mighty interesting. Through this process, is it too much of a vision to picture some of our great public spirited men becoming as earnest supporters of our water systems as they are of various other great community interests?

These men are giving vast sums of money each year to our universities for equipment and expert service. They are endowing hospitals and establishing free clinics and immense institutions and bureaus for research work are carried on through their aid. All of these activities are encouraged, because through them it is thought that a better and a healthier place to live in will result.

Is it not worth the attempt at least to point out to this class of men, who love to give generously where they can give wisely, the great value of our public water supplies and how with their help that value may be immensely enhanced to the great benefit of the community and to the everlasting credit of the benefactor? Entire water sheds at present populated and thus, potentially, a source of danger to the water supply, could be purchased, cleared of all human habitations and turned into splendid forest and park preserves, practically insuring the supply forever against the contamination we so much dread. Model shops and laboratories could be built, where equipment could be tested and further experiments made in purifying, softening and rendering commercially fit the many waters at present objectionable. With no fear of financial disasters threatening us—duplicate supply mains, pumps, filters and other appurtenances would be the invariable rule and the factor of safety to our municipalities become more nearly what it should be, rather than what it now so often is—negligible. But you will ask—are not these things to be obtained by taxation, just as are pavements, policemen and playgrounds? Yes, but only in part and often after

the demands of these and other more apparent and popular—but much less essential—things have received their quotas. The resultant budget is always a compromise between what is desired and proper, and what can be just gotten along with.

The great philanthropists of our cities recognize that a surgeon can not get the best results with an incomplete outfit of instruments, in a poorly equipped operating room. Why not treat us with the same thoughtfulness for we are also doing our part in saving and preserving life. Again, let us try and direct more general attention to the aims and capacity for doing good of this American Water Works Association.

"The advancement of knowledge in the construction and operation of water works" expresses very clearly our object and "the exchange of information and experience among its members" expresses vast possibilities.

Who can estimate the value of a great central reference bureau (which I suggest may be one of our great accomplishments), where the experiences and practices of all the water systems in the country would be catalogued and made easily accessible? Because of the great expense of collecting and tabulating such data, our efforts in this direction have been slight and our attainments meagre.

Our water works magazines and engineering journals have done at times very valuable work in collecting various water works statistics, and their labors along those lines deserve our warmest praise, but I feel that logically the process should be reversed and this Association should be in a position to furnish all such information to these journals when and as often as requested, rather than the other way around. This condition can not however be brought to pass with our present financial resources and methods, and for the same reasons the work of our many and important committees is hampered where it should be encouraged and unfettered. It is impractical to make our dues—even with a greatly increased membership—sufficiently large to properly finance all of these projects, but it may be possible to so present our case that certain enlightened municipalities and far sighted individuals, may see the wisdom of advancing funds to this Association for some of these purposes. We have done just this thing to a certain extent in electrolysis research work, and with the proper management it no doubt could be done again.

There are many other opportunities, besides those I have suggested, which lie ahead of us. We can not grasp them all perhaps, but we have the men and the ability and if with these we develop the inclination to accept even a few of these favorable chances for service, I believe our position among the great national societies will be safe and unchallenged.

In closing I must tell you that I have appreciated and enjoyed very greatly the honor of being the President of this Association and I could wish my successor nothing better than that you show to him the same courtesy, kindness and assistance that you have accorded me.

THE APPLICATION OF COLLOID CHEMISTRY TO THE FILTER-PRESSING OF SEWAGE SLUDGE[1]

By John Arthur Wilson, Wm. R. Copeland and Henry Mills Heisig[2]

The viewpoint of modern colloid chemistry is the logical one from which to attack the basic problems of sewage disposal because the solid matter of the average city sewage is chiefly an agglomeration of extremely complex bodies in the colloidal state. The fundamental object of most systems of sewage disposal is to separate these bodies from the water, and this is primarily a problem of colloid chemistry.

By colloid chemistry we mean simply the chemistry of substances having a very large specific surface (surface area per unit weight), a condition now referred to as the colloidal state. The properties of the surfaces of a body are so different from those of the main mass that any great increase in specific surface, as by repeated subdivision, results in a complete change of properties of the substance. This necessitates a change in the method of classifying substances according to properties when they have been reduced to the colloidal state.

One of the reasons for the tremendous success attending the application of colloid chemistry to industrial problems is that substances of widely different chemical constitution assume many important properties in common when in the colloidal state. The value of this fact will be apparent in sewage disposal where it is necessary to deal with innumerable substances so complex as to make successful treatment by the older conceptions of chemistry practically impossible.

The colloidal matter of sewage can be divided into two general classes: the *dispersoids* and the organized *jellies*. The dispersoids consist of extremely finely divided substances, called the *disperse*

[1] Presented at the Cleveland Convention, June 9, 1921. Discussion is invited and should be sent to the Editor.

[2] Sewerage Testing Station, Milwaukee, Wis.

phase, distributed throughout the water, which is called the *dispersion medium*. The disperse phase is so finely divided that the particles can be seen only with the aid of the ultramicroscope. But the jellies can be seen with the naked eye in the form of protein and cellulose fibers, tissues, hair, etc. The great specific surface of the dispersoids is due to the fineness of subdivision of the disperse phase, but that of the jellies is due to the internal arrangement of the atoms, which form a three-dimension network with interstices sufficiently large to permit the passage of water and the simpler molecules. One marked distinction between the two classes is that the dispersoids behave like a solution of the colloidal matter in water and the jellies like a solution of water in the colloidal matter.

The surfaces of these colloidal bodies possess electrical charges which tend to prevent their separation from the water, and the more so the greater the value of the charge. Our basic problem is thus to reduce the value of this electrical charge to a minimum.

The most effective means of lowering the value of the electrical charge on colloids are to alter the acidity of the solution in the proper direction or to add a substance carrying a sufficiently high electrical charge of sign opposite to that on the colloid.

In many dispersoids the disperse phase is positively charged in acid solution, but as more and more alkali is added the value of the charge is gradually reduced to zero, the *isoelectric point* of the colloid, which then coagulates and settles out. But now, if still more alkali is added, the coagulated colloid may take on a negative electrical charge and redissolve. Jellies, on the other hand, swell, or increase in volume, in acid solution by absorbing water and are then positively charged, but if increasing amounts of alkali be added, the jelly shrinks, giving up its absorbed water until, at its isoelectric point, the amount of absorbed water reaches a minimum. When the alkalinity is further increased, the jelly swells again and becomes negatively charged. The electrical charges can also be reduced by adding other colloids of opposite sign or polyvalent ions, such as phosphate for positively charged colloids and chromium or aluminum for negatively charged ones; but here too the addition of an excess of the coagulating agent may result merely in changing the sign and preventing coagulation.

At the Milwaukee Sewerage Testing Station the raw sewage is treated by the activated sludge process, the molecular mechanism of which is still a matter of speculation, although it possibly in-

volves the formation of new colloidal bodies of opposite charge to that on the unchanged colloidal matter followed by coprecipitation of the oppositely charged bodies. The sludge obtained from this process, however, is not at its isoelectric point, but is negatively charged, and is therefore not in the best condition for filter-pressing.

The experiments reported in this paper form part of a larger work undertaken for the purpose of finding the average isoelectric point of the sludge and determining the conditions best suited for its dehydration.

Experimental. The laboratory experiments which proved most fruitful consisted in measuring the effect of a change of reaction of the sludge upon its rate of filtration. The apparatus consisted of a high vacuum pump connected to twenty filter flasks fitted with Buechner funnels. In each test twenty identical samples of sludge were treated differently, all were thrown onto filters at the same time, the rates of filtration were noted, and the final reaction of the filtrate determined. As soon as each sample was completely filtered, the flask was cut off from the main line so as not to reduce the vacuum on the others. In each preliminary investigation the series of twenty covered a wide range of treatment, but in the later work the procedure was refined by confining the series to a comparatively narrow range covering the critical points.

Method of recording acidity. It has been generally recognized for some years that the active constituent of all acids is hydrogen ion and that the activities of acid solutions can be represented quantitatively only in terms of the hydrogen-ion concentration. Likewise the active constituent of all alkalies is hydroxide ion. Since hydrogen ion and hydroxide ion unite to form water, there is a definite reciprocal relationship existing between the concentrations of these two ions in all aqueous solutions such that the value of one determines the other. In fact, the product of these two concentrations is constant, whatever the acidity or alkalinity of the solution. For this reason it is possible to record hydroxide-ion concentration in terms of hydrogen-ion concentration, making one scale do for both acid and alkaline solutions. But this gives a working range of hydrogen-ion concentration of from about ten moles to one quadrillionth of one mole per liter. (One mole of hydrogen ion is 1 gram; one mole of hydroxide ion 17 grams.) For the purpose of record it has consequently been found advisable to use the logarithms of these values, reducing the range to 16 units.

The term pH is now commonly applied to the logarithm of the hydrogen-ion concentration, with change of sign. A pH value of 1 means 0.1 mole per liter; a pH value of 2 means 0.01 mole; a pH of 3 means 0.001 mole, etc. A pH value of 7 indicates a neutral solution; one less than 7 an acid one; and one greater than 7 an alkaline one.

Effect of change of acidity. In the first series of experiments 90-cc. portions of sludge were treated with 10 cc. of standard sulfuric acid or sodium hydroxide in order to give a wide range of pH values. The rates of filtration were noted and the pH values of the filtrates determined. With some modifications this procedure

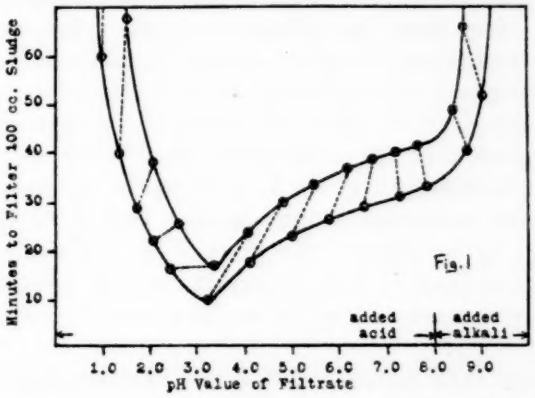


FIG. 1. Lower curve is for samples filtered 15 minutes after treating with acid or alkali; upper curve for samples filtered 24 hours after treating. Dotted lines connect the points for samples treated exactly alike; the lower curve shifts toward the upper one during the 24-hour period, the individual points moving in the directions indicated by the dotted lines.

was continued daily for months in order to cover all kinds of sludge and to discover the extreme variations to be expected. It is remarkable that the sludge showed very little variation in a number of important properties. The pH value of the sludge itself varied only from 7.7 to 8.3, with an average of about 8.0. The addition of alkali, such as lime or lye, invariably increased the time of filtration. The average isoelectric point was confined to the rather narrow limits 2.8 to 3.6. The effect of change of pH value is shown graphically in the lower curve in figure 1, which is typical of most of the sludges encountered. It will be noted that the addition of very little alkali has a very powerful effect in retarding the filtra-

tion. The addition of sulfuric acid continues to increase the rate of filtration until a pH value of 3.2 is reached, after which further addition of acid has a marked retarding effect. By adding the proper amount of acid the rate of filtration was often increased by about 400 per cent and considerably more when the sludge was not in good condition. In every case the clearest filtrates were obtained from the samples having the greatest rate of filtration.

Although the average isoelectric point was practically the same for all types of sludge, the actual time required for the filtering of a fixed quantity was very variable, even at the same pH value. With two samples at the same pH values and having the same percentage of solid matter, one might require twice as long to filter as the other. Much study has been given to this difference in condition of the sludges and it has been found that at least two factors have a bearing on it; one the temperature of the raw sewage at the time of aeration and the other the extent to which decomposition has taken place after the aeration process. When the sewage is aerated at a temperature of 60° F. or over, the resulting sludge is in much better condition for filter-pressing than when the sewage is aerated at 40° or under. The effect of decomposition after the aeration process is also a most important one and is responsible for peculiar time changes with which we have been confronted in our work.

Time changes in the condition of sludge. Dissolved materials diffuse into jellies comparatively slowly and it was apparent from the start that the pH value of the sludge would slowly change for some time after the addition of acid or alkali due to their slow absorption by by the jellies. Accompanying this drift in pH value one would naturally expect a change in the rate of filtration. In order to study the effect of this drift, we usually set up the series in duplicate, filtering one set immediately after treating and the other 24 hours later. A pair of such duplicates usually gave the results shown in figure 1. At times, however, the results were like those shown in figure 2, and it was at first thought that the difference might have been due to the infrequent dumping of large amounts of an unusual type of industrial waste. It appears at present as though the effect is due rather to decomposition of the sludge after the aeration process. A sample of sludge which had given a pair of curves like those in figure 1 was kept in the warm air of the laboratory for 24 hours and then the experiment was repeated, but this time it gave a set of curves like those in figure 2.

While the difference between the two curves in figure 1 is probably due partly to the slow absorption of acid or alkali by the jellies, it is probably due in a greater measure to slow decomposition. This is more obviously true for the curves in figure 2, which seems to indicate that this decomposition proceeds at the greatest rate at a pH value of about 5.3.

In the upper curve in figure 2, the steepness of the slopes either side of the isoelectric point shows that decomposition makes the rate of filtration much more sensitive to changes in pH value. This introduces a serious difficulty when dealing with concentrated sludges during the winter time when the aeration of the sewage takes place

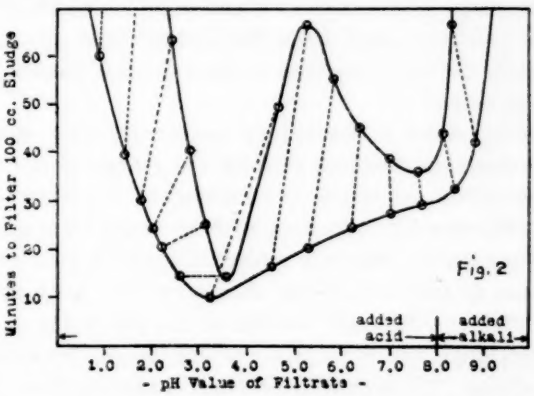


FIG. 2. Same as figure 1 except for an initial difference in the character of the sludge. The peculiar maximum in the 24-hour curve appears to be due to products of putrefaction.

at a low temperature. Because of the danger of further decomposition, such sludge must be filtered as soon as possible after treating. But the drift in pH value of concentrated sludge is considerable and the rate of filtration of this sludge is very sensitive to changes in pH value. The optimum range is so narrow and the drift so great that whatever the initial pH value, the sludge would not remain within the optimum range for more than a fraction of the time required for pressing. But by diluting the sludge before acidifying, the extent of the drift in pH value is reduced because the sludge then has a greater reservoir of acid from which to draw. We have actually demonstrated that the time of filtration of such a sludge can be materially reduced by diluting with an equal volume of water

before treating, even though more than twice as much water must then pass through the filters. On the other hand, diluting a sludge which is in good condition may increase the time of filtration by increasing the amount of work involved in expelling water from the sludge.

The curves in both figures 1 and 2 show how to acidify a sample of sludge to get the best results. The isoelectric point of the sludge which has stood 24 hours is always slightly higher than that which has been filtered at once, but corresponds to a treatment which gave a pH value slightly lower than the isoelectric point in the series filtered at once. This treatment is the one that will give the best results in practice, where several hours may be required for each pressing. It will be noted from the curves that, while the pH value increases, the time required to filter a fixed quantity remains practically constant.

Unless some means is devised to counteract the effect of low temperature upon the aeration process, the design of the plant and system of operation are likely to be seriously complicated, since a much more extensive filter-pressing system would be required whenever the temperature of the raw sewage dropped appreciably. The cost of heating 65,000,000 gallons of raw sewage daily would seem to be prohibitive. Although control of the pH value is a step in the right direction, it will not entirely bridge the gap between summer and winter sludge. It appeared possible, however, that this might be accomplished by the addition of substances carrying a sufficiently high positive electrical charge.

Action of salts yielding polyvalent ions. Because the sludge carries a negative electrical charge it was evident that good results could be expected only from positively charged polyvalent ions. It was then demonstrated that sodium phosphate greatly retards the rate of filtration while aluminum and chromium sulfates accelerate it, provided an excess is not used. These salts hydrolyze readily and introduce complications by altering the pH value, but this difficulty was overcome by adding an amount of salt based upon the percentage of solid matter and then regulating the pH value with acid or alkali. The increase in rate of filtration brought about by the use of aluminum or chromium sulfate at optimum acidity was much greater than could be obtained by acid alone. Where acid alone increased the rate of filtration by 400 per cent, the proper use of aluminum sulfate and sulfuric acid gave an increase of 900 per cent, which will

nearly, if not quite, overcome the difference between summer and winter sludge.

Figure 3 shows a typical set of curves obtained in the laboratory on the same sludge with and without aluminum sulfate. It is interesting to note that the aluminum sulfate actually retards filtration on the acid side of the isoelectric point, where the sludge is positively charged. Another interesting fact is that the aluminum sulfate is most effective at a pH value of about 4.3. This is not surprising in view of the fact that the isoelectric point of aluminum

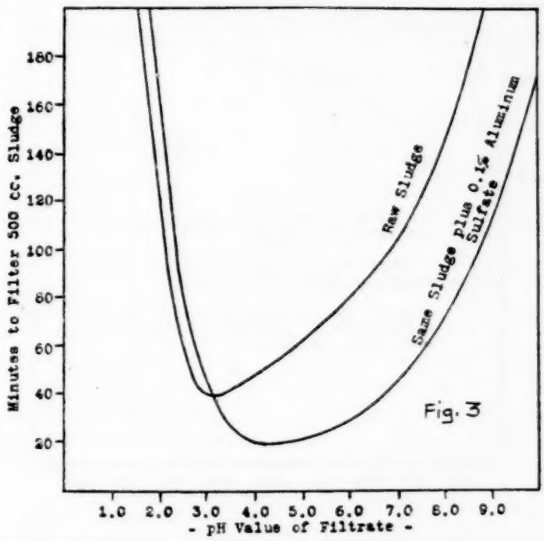


FIG. 3. Showing how the addition of aluminum sulfate before treating with acid or alkali changes speed of filtration.

hydroxide lies at about 7.5 and that of the sludge at about 3.0. At a pH value of 7.5 the aluminum hydroxide would not carry any electrical charge and would consequently be of little value in coagulating the negatively charged sludge. Somewhere between 3.0 and 7.5 the negative charge on the sludge must be equivalent to the positive charge on the aluminum complex, and this point appears to have been about 4.3 for the conditions of our experiment. The curves show the time required to filter 500-cc. samples of treated sludge. By using larger samples in these tests we were able to make more accurate studies of the change of rate of filtration with time.

In the experiments with aluminum sulfate, it was customary to set up each series in duplicate, as in the experiments with acid, filtering one series 15 minutes after treating and the other 24 hours later. Time changes were found similar to those shown in figures 1 and 2, which indicates that decomposition of the sludge proceeds, even in the presence of aluminum sulfate. Studies are now being made of the putrefaction of sludge and its relation to the aeration process.

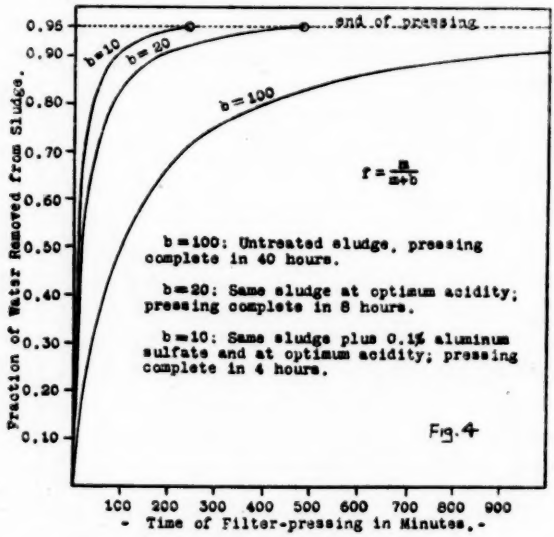


FIG. 4. Showing how the rate of filtration decreases with time, but according to the method of treating the sludge.

Chromic sulfate gave results very similar to those of aluminum sulfate. Ferrous sulfate, on the other hand, showed no improvement over acid alone. The lesser effect of this salt is, of course, easily explained by the fact that the ferrous ion has only a double electrical charge, whereas the chromium and aluminum ions carry triple charges in acid solution.

Time changes in rate of filtration. In filter-pressing, it had always been noted that the rate of filtering continued to fall throughout the pressing. Readings were taken at frequent intervals on an experimental plate press and the fraction of water removed was plotted against the time in minutes. This was repeated for sludges of

different types and treatments, but in every case the curve obtained was an hyperbola of the familiar die-away type and corresponded to the formula $f = m/(m + b)$, where f is the fraction of total water removed, m the number of minutes which have elapsed since the start of the pressing, and b a constant depending upon many different factors. Keeping the press, filter bags, quantity of sludge, and percent of solid matter in the sludge constant, then b becomes an index of the condition of the sludge, which will vary with the treatment.

TABLE 1

Comparative data on large scale pressings and laboratory tests

	SLUDGE 1	SLUDGE 2	SLUDGE 3	SLUDGE 4
Gallons of sludge pressed	2871	2673	3193	3228
Percent water in sludge	98.98	98.83	99.06	98.95
pH value of sludge	7.4	7.7	7.4	7.6
Cubic centimeters of sulfuric acid added per gallon	none	2.50	1.04	2.65
Grams of aluminum sulfate added per gallon	none	none	3.15	none
Initial pH value of treated sludge	7.4	3.9	4.4	2.7
Final pH value of treated sludge	7.7	6.0	6.6	6.0
Pounds of cake produced	1407	1118	1275	1240
Percent water in cake	84.4	81.4	82.0	81.1
Hours required for pressing	23.8	6.0	5.3	6.4
Hours required to filter 500-cc. treated sample in laboratory	0.62	0.15	0.083	0.15
Ratio of time consumed in large scale test to time consumed in laboratory test	38	40	64	43

Note: Sludges 2, 3, and 4 left the filter bags clean and in good shape for further pressing, but sludge 1 left them so gummed up that they could not be used again without washing.

Figure 4 shows the effect of aluminum sulfate and of optimum acidity upon the change of rate of filtration as well as upon the value of b. In this case the pressing is taken as complete when 96% of the water has been removed.

According to the formula, for any fixed value of f, m is directly proportional to b. This would seem to justify our method of comparing sludges by filtering equal quantities. If it takes twice as long to filter 100 cc. of sludge A as of sludge B, we should expect

it also to take twice as long to filter 100 gallons of sludge A as of sludge B. In other words, whatever the quantity of sludge to be filtered under fixed conditions, the percentage increase or decrease in time required caused by a given treatment should be the same whether the test be made on a small scale in the laboratory or on a large scale in the plant, provided, of course, that secondary disturbing influences are excluded.

At the time of writing this paper, we had just begun to apply the laboratory data to large scale pressings and fortunately there is sufficient data now available to show that the theory that the laboratory tests could be applied almost quantitatively to large scale work was not unsound. This is clearly shown in the data given in table 1. All large scale pressings were made on the same press and the laboratory tests on Buechner funnels and filter paper as nearly alike as possible. Where 0.62 hours was required to filter a 500-cc. sample of untreated sludge in the laboratory, it took 23.8 hours to press 2871 gallons. of this same sludge. Where it required only 0.15 hour to filter 500 cc. of treated sludge in the laboratory, it took 6 hours to press 2673 gallons of this same sludge. The laboratory test showed that treating with acid reduced the time required to filter to about one-fourth and this ratio was also found in the large scale pressing. The ratio of the time consumed in the large scale test to time consumed in laboratory test is apparently about 40. There is an apparent discrepancy in the case of the sludge treated with aluminum sulfate, but this is probably due to the fact that the laboratory samples should have been larger as it is difficult to estimate the time of filtration more closely than to one minute, which is a large fraction of the approximately five minutes required for filtration in the laboratory test. The laboratory samples should be larger for another reason also; the drift in pH value in a 6-hour pressing in much greater than in the laboratory tests and will have an effect upon the ratio found.

More experiments both in the laboratory and plant will be carried out as rapidly as possible, but we believe that enough has been done to prove the enormous importance of colloid chemistry in problems of sewage disposal and the necessity for controlling the pH value of sludge to be pressed efficiently. The entire subject will probably be found to apply with equal force in problems of water filtration.

MUNICIPAL WATER RATES[1]

By E. E. Bankson[2], D. E. Davis[2] and C. A. Finley[3]

The development of scientific rate making has been coincident with the advent of the Public Service Commission, wherein the majority of cases dealt with are the relatively small privately owned plants susceptible to considerations in operation which are often entirely submerged and of little value in the operation of large municipally owned plants. This paper is presented with the view of creating further interest in this much neglected field.

The operation of a municipally owned plant affords the opportunity for rate making on the basis of true equity and free from temptations to adopt policies of financial expediency appealing to privately owned plants. There are many elements in common to both plants creating influences in rate making which are often reflected in widely varying results, due to the radical differences in policy adopted by the directors of a private corporation in the one and the legislators of a municipality in the other case.

The operation of privately owned plants in many states is under the jurisdiction of the Public Service Commission, where a revenue is recognized sufficient to provide a fair return on the fair value of the property, in addition to operating expenses and an allowance for depreciation of plant. The reasonableness of rates imposed by a private water company would necessarily be measured by application of the rulings of the Public Service Commission.

The operation of municipally owned plants is generally not under the control of the Public Service Commission, which fact permits different principles to be applied in the two cases. The duty of the Commission is to protect the interests of both the consumers, as members of the community, and the water company, as a private concern; but the consumers may exercise their control of a municipally owned plant through the power of their vote.

[1] Presented before the Cleveland Convention, June 7, 1921. Discussion is invited and should be sent to the Editor.

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[3] Managing Engineer, Bureau of Water, City of Pittsburgh.

The opportunity for variations between municipal rates results from differences in the so-called ownership of a municipal plant. The latter depends on the proportion of the investment contributed by property through tax assessments as contrasted with excess earnings gathered from water revenue and invested in plants. The reader will here understand that the expression "so-called ownership" is used as a convenient term to indicate the source of money that built the plant. Unless this factor is recognized in the building of the rate schedule, some discrimination may result toward one or the other of the contributors to the plant cost, i.e., the property owner on the one side or the water consumer as such on the other side. The equity of rates imposed by a municipal plant would seem to depend, therefore, on this seat of so-called ownership.

A municipality may operate its water plant at a profit as a separate source of municipal revenue if it is disposed to do so and the law does not prevent. Such operation may favor the property owner who does not take water in proportion to the value of his property, such as owners of vacant property or of extremely valuable property requiring a small quantity of water. On the other hand, if the plant be operated at a loss with the deficiency repaired from the general tax levy, the water taker or consumer as such would then be favored at the expense of the tax-payer.

The thought often exists in the mind of the layman that substantial justice will be done if all revenue is derived from water sales, since the consumer and the property owner are substantially one and the same. That this is not strictly true is evident when we consider such extreme cases as the valuable vacant property or the large office building, which enjoys water service, fire protection, and increased property value out of all proportion to the relatively small charges for water used, on one hand, and the very large consumer of water, on the other, whose business is housed within a relatively inexpensive building or property.

The decision to operate a municipal plant at a profit, or at a loss, however, is to be determined in part by administrative policy, rather than as entirely a question of scientific rate making. If accurate cost analysis is to play any part in the problem of rate making, however, it must precede and remain separate from questions of administrative policy, except that the term "cost of service" may be subject to different interpretations according to the administrative policy obtaining. The results of cost analysis are to be used

for the purpose of moulding or indicating the correct administrative policy in this respect. The major purpose of this discussion being "Total Cost of Service," resulting in the "Rate Base" or "Total Annual Burden" and the equitable distribution of this burden among the various consumers of a municipally owned water plant, we intend that any mention of administrative policy in connection with cost be considered only as contributory discussion.

Cost of service. Cost of water service as deduced from the practice of Public Utility Commissions in their control of privately owned plants, is made up as follows: (a) Fair return on a fair plant value, (b) an allowance for plant depreciation, (c) cost of plant operation and maintenance, wherein the item for "fair return" incorporates any profit permitted for the utility. The three items indicated are based on used and useful plant value.

This discussion of absolute cost of service rendered by a municipal water plant will not incorporate an item of profit, and consequently the item of "fair return" for private plant will be replaced by an item which may be designated as "interest on capital invested." Where the so-called ownership of plant, bonded indebtedness, sinking fund, and interest rate paid may vary with each plant, it follows that the total cost of service will vary with each municipal plant, though the terms "depreciation and operation" carry the same meaning as indicated above. This "cost of service" as distributed to the consumers through the medium of the rates charged will be further dealt with under the heading "Distribution of the Burden."

Ownership of plant. There is no contention that the City does not own the plant, but there does appear to be a difference in equitable rates, dependent on the source of funds for plant purchase. The two sources are the general tax levy and the charges for water service, as illustrated in the following comparison.

The water works plant of the City of Toronto, Canada, appears to be bonded to more than its present value, and Akron, Ohio, only slightly less, as indicated in the tabulation of "Plant Statistics." This means, in a sense, that the bond holders own the plant and the cost of service must incorporate the total interest on the bonded debt. Unless, in addition, the water revenue provides also a sinking fund for retirement of bonds, the water takers as such will never hold any equity in plant account. If the operating revenue, in this case, should provide a sinking fund, in addition to interest and operating cost, the rates would ordinarily need to be as high or higher than those permitted for a private plant.

The water works plant of the city of Erie, for purposes of this discussion, may be considered free of debt. Since there are no interest or sinking fund charges to meet, one might easily and erroneously conclude that the water rates in Erie should be much less than in Toronto. Such is not necessarily the case, for the water rates in Erie provide the only source of revenue for plant extension and replacements. In other words, the water takers in Erie are paying for their plant as they go along, and for the past ten years this cost has been approximately equal to 6 per cent on the plant cost. This item therefore takes the place of interest and sinking fund for a bonded plant in the "cost of service" for Erie. If Erie should ever stop growing, however, and no further plant extensions should be necessary, this item would disappear from the "cost of service" and the water rates should decrease accordingly, whereupon the advantage of this position would be more apparent. From the above discussion, it is evident that the water takers have provided the funds for investment cost of the Erie plant and in the spirit of this discussion we might say that the water takers or consumers own the Erie plant.

The water revenue in many other cases is insufficient to carry the annual burden and any bonds retired would indicte a credit to the general tax levy, which should entitle the tax levy to the regular city interest rate on all plant investment actually made. In setting up the "cost of service," the general tax levy should receive a ledger credit for providing these funds, resulting in a corresponding charge to the water takers, which would appear in the "cost of service" distributed among the individual water accounts through the rates applied, with public service and fire protection carrying a proper portion of the cost.

We understand that the present policy in the city of Cleveland provides that the ownership of small distributing street mains and service lines to the curb is vested in the property owner. At any rate he foots the bill and carries that entire burden by direct assessment, as for sewers or for street paving. In the City of Erie, however, the total burden is carried by the Water Department, thereby creating a difference in the basis for equitable rates in the two cases. In the one case, the consumer has gone down in his pocket and paid outright for his service line and street main, or, if he is a renter, he meets that burden through his house rent, while in the other case the burden of said items appears in the water rates, corresponding to a

return on investment. This variation results from the different location or seat of plant ownership of the items in question.

The city of Pittsburgh offers a third comparison in this connection. There the property owner assumes the burden of the service line and the Water Department that of the service mains. A difference as to ownership of meters offers yet another comparison. The purpose of presenting the foregoing examples is to lend support to the statement that the rates charged for water in one city offer no evidence of equitable rates to be charged in another city or in a private plant. Each case must be analyzed separately and must stand on its own merits under the full conditions obtaining in each instance.

In support of the thought that each schedule of rates stands alone, we tabulate, on the following page, data from replies to questionnaires sent to several cities. This tabulation indicates, among other things, that the bonded debt and resulting fixed charges vary from 0 per cent to 100 per cent, that the plant value varies from $19.75 to $88.00 per capita and that the operating cost ranges from $0.92 to $3.22 per capita or from $18.00 to $95.00 per million gallons.

Another deduction from this table, which may be of interest to some, is that an average plant value is slightly less than $40.00 per capita, while the average operating cost for 1919 was slightly less than $40.00 per million gallons, although this figure would be reduced in normal times.

It is entirely possible that there may have been some discrepancies in interpretation of both questions and answers preliminary to the formation of this table, which would give erroneous results, but we have no evidence of error in the figures submitted. We use them here as illustrative of our position. The results should dispel any idea that water rates in different cities may be compared, for a comparison in total means nothing.

Service rendered. The functions of a water works plant are admittedly two-fold, that of furnishing a water supply for general consumption and for fire protection. Since this discussion is based on the principle that "the rates charged for any service should be in proportion to the cost of such service," it becomes necessary to make a careful analysis of all functions and duties assumed by the water department and of all service rendered.

Fire protection service is rendered to property or to property owners in proportion to the value of the property protected. Charges for such service, therefore, should be entered directly against the prop-

erty or against the general tax levy. General water service is rendered to persons or industries largely in proportion to the water delivery, with no necessary relation between value of property and quantity of water delivered. To make a proper accounting for all service rendered, the charge for water cannot properly cover fire protection, for there is no necessary relation between the two, and in fairness to all concerned, a charge for fire protection must appear separate in a complete schedule for equitable rates.

The provision of a water supply for fire protection service creates an increase in plant investment and in plant operation over and above the costs which would be sufficient for general water service. The exact cost of fire protection service has been somewhat in doubt within the limits of the two methods of computation used, that is, the excess method and the proportional method. After a careful analysis has been made of fire protection service rendered by any plant, a cost for this service, however, can with fairness be established and a charge indicated in that amount. In the case of the City of Pittsburgh the ratios chargeable to each service were obtained from available records of actual demands. The result was checked fairly well by the equation proposed by Metcalf, Kuichling and Hawley in the 1911 Proceedings of this Association.

General water service may first be separated into two groups as public service and private service. If the tax levy carries the burden of plant investment this may amount to more than the cost of the public service received by the city and by property in general. In such a case the ledger should show a credit to that extent, in this way offsetting the charge for public service. General water service is again divided according to flat rate service and metered or measured service.

Flat rate service. The flat rate method of charging for water service, a heritage to us from pioneers in the water works field, carries the approval of the wasteful user, because it permits his extravagance at public expense. It does not seem to disappear rapidly through a process of the survival of the fittest. It would seem, therefore, to devolve wholly on the water works men to gradually make obsolete the flat rate system. Flat rate charges or assessments are admittedly inequitable and conducive to wasteful habits. But being yet with us, they should always appear in excess of meter rate charges, for the same amount of service, with the hope that such a practice will create converts to the metered or measured service method, although experience shows the latter to be not always the case.

The average domestic flat rate in the city of Pittsburgh is 55 per cent in excess of the meter rate for similar service, but every flat rate consumer has the option of transferring to measured service if he so desires. Even with this high flat rate there remains under flat rate service approximately two-thirds of the total number of consumers with no apparent desire to avail themselves of the economy offered. In fact most of the metering accomplished has been of a compulsory nature.

The Pittsburgh plant has a capacity in excess of fully metered requirements. It is interesting to discover through cost analysis that no economy may be effected by metering the entire city at once; or at any rate in excess of that necessary to reclaim plant capacity from wasteful service to useful service, or additional demands, as conditions may require. In the case of Erie, however, the plant capacity has been reached under the present flat rate policy, and it is clearly evident, in the interests of economy, that a policy of metering domestic consumers should be adopted.

Metering may reduce domestic consumption by more than half, which has the same effect as increasing plant capacity. It is far cheaper to meter than to build additional plants. It would be poor economy (in fact wasteful) to create additional plant capacity for the purpose of supplying flat rate consumers, instead of placing them under measured service. Aside from discussion along lines similar to the above, we cannot see that flat rates have any place in scientific rate making, for flat rates are subject to the laws of neither science nor equity.

Measured service. In the case of the city of Pittsburgh, the computed demand under fully metered conditions would show a reduction of 40 per cent from the present pumpage. Such a reduction represents no curtailment of useful service, but it represents rather the reducible leakage and careless running of water to waste, which simply flows down the sewer and does service to no one.

There appears a common error among water works men and engineers of overestimating the amount of water which will be used when a city is fully metered, with the result that a financial deficit appears as metering progresses. This tendency to overestimate is a logical result of a habit formed in designing plant capacity for maximum conditions. Such a designer carries this habit over into the field of rate making, where he discovers, too late, that his measuring stick was too large and the revenue is not realized as computed.

We have also observed a tendency, on the part of the inexperienced, to use the present pumpage of a flat rate system, as the starting point to forecast future revenue under fully measured service. They apparently forget that there is no reliable relation between the two and that revenue is indicated by the dial on the consumer meter rather than by the pump counter.

Such errors are entirely unnecessary today with the progress which has been made by those who are successful in this department of water works affairs. The revenue under fully metered conditions may be fairly and safely computed by an intelligent analysis of complete and detailed consumer data in each case. To make this clearer we tabulate below the results of two cases coming within our experience.

CONSUMER CLASS	AVERAGE GALLONS TAKEN PER YEAR	
	St. Mary's, Pa.	Pittsburgh, Pa.
1. Single spigot consumers	7,500	32,000
2. Single spigot plus toilet	10,300	42,000
3. Set of complete fixtures within the building	27,800	50,000
4. Set of complete fixtures including sprinkling	45,200	64,000

The high figures for Pittsburgh might be explained by the fact that the excessive smoke and dust demand more washing on the part of the public. In addition, the pressure at the spigot is rather

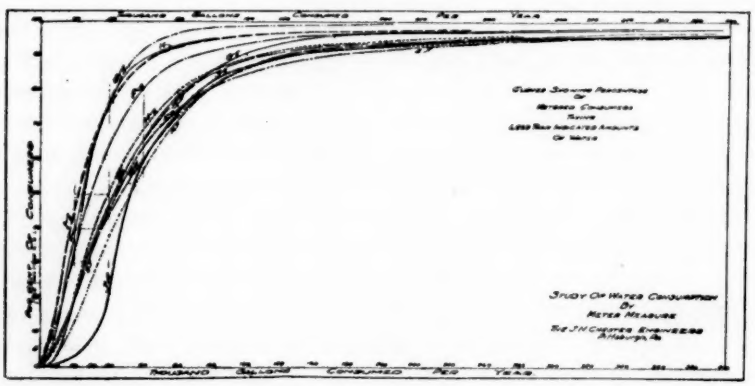

FIG. 1. CURVES SHOWING PERCENTAGE OF METERED CONSUMERS TAKING LESS THAN INDICATED AMOUNTS OF WATER

high, an average of 79 lbs., while the maximum at different points is in excess of 100 lbs. The divergence of the Pittsburgh results, in excess of the normal, is clearly shown by means of consumer curves and tabulation as attached herewith. The curve for Pittsburgh appears to the right of all other curves and is designated as curve "J."

Water consumption, as shown by actual meter readings (forecast for Erie)

CITY OR BOROUGH	GALLONS PER YEAR PER METER	GALLONS PER DAY PER METER	GALLONS PER CAPITA PER DAY—5 PERSONS PER METER
1. Popular consumption			
Knoxville, Tenn.	25,000	68.5	13.7
Jefferson City, Mo.	27,375	75.0	15.0
St. Marys, Pa.	23,000	63.0	12.6
Scottdale, Pa.	17,000	47.0	9.4
Ellwood City, Pa.	18,000	50	10.0
Milwaukee, Wis.	25,000	68.5	13.7
Forecast for Erie	31,000	85	17.0
Pittsburgh, Pa.	42,000	115	23
2. Consumption at 50 per cent point on consumer curve			
Average of ten American cities (including Cleveland)	42,000	110	22.0
Knoxville, Tenn.	27,000	74	14.8
Jefferson City, Mo.	26,000	72	14.4
St. Marys, Pa.	25,000	72	14.4
Scottdale, Pa.	22,000	61	12.2
Ellwood City, Pa.	27,000	74	14.8
Madison, Wis.	36,000	99	19.8
Milwaukee, Wis.	42,000	110	22.0
Forecast for Erie,	42,000	110	22.0
Pittsburgh, Pa.	52,500	144	28.8

The relation between fixtures and annual consumption was developed in the Pittsburgh case as shown by the following curve.

Distribution of the burden. Meter rate schedules are generally one of three types: (1) Straight price to all per 1000 gallons, (2) minimum charge type, (3) service charge type. Nos. 2 and 3 are on the basis of either a straight price or a sliding scale in addition to certain fixed charges. It is generally conceded that it costs more per 1000 gallons to serve a small than a large consumer. If this fact be admitted, we thereby eliminate the straight-price or flat-price-to-all idea.

A minimum charge type sliding rate schedule can be constructed which would closely approach the costs of rendering the service, but the Public Service Commission of New York has ruled against the minimum charge type in a gas case in the following words which apply equally well to water:

The minimum gas rate is inequitable. A sample case cited is the best proof. Mr. A. and Mr. B. are in the minimum class, which is placed, say, at $1.00. Mr. A. used 90 cents worth of gas a month; he pays $1.00. Mr. B. uses 20 cents worth of gas a month; he also pays $1.00. If the interest on the service investment to that residence or office is 50 cents, the company sustains a loss from Mr. A. of 40 cents that must be made up by some other consumer, while it has made a profit of 30 cents off Mr. B.

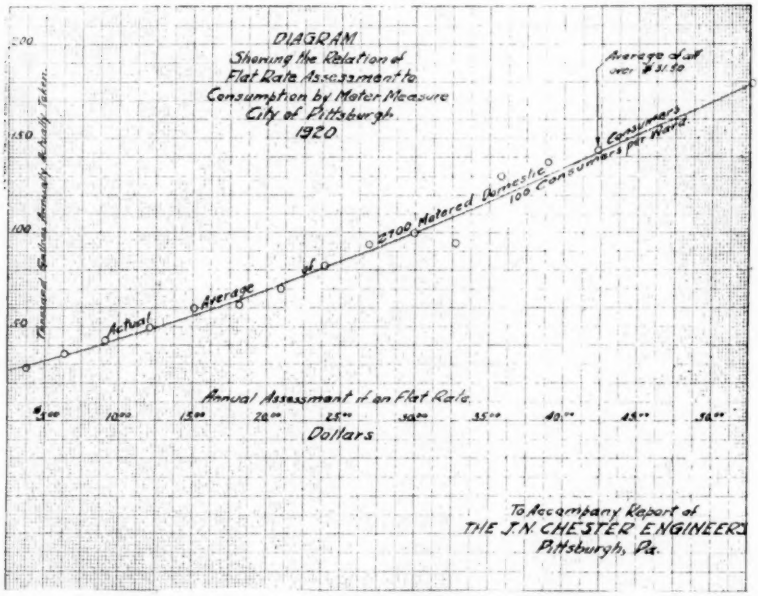

FIG. 2. RELATION OF FLAT RATE ASSESSMENT TO CONSUMPTION BY METER MEASURE

The service charge is recognized by the New York Commission in these words, "A service charge . . . . is a legal and just charge if properly adjusted as to amount." The association of Boroughs in Pennsylvania, on advice of their counsel, has recently withdrawn a proposed bill intending to make the service charge illegal in Pennsylvania. These and many other incidents seem to indicate to the writers the increasing recognition of the service charge.

Service charge limitations. Advocates of the service charge have included portions of the total annual burden under this charge, ranging all the way from "simple consumer charge" to "entire fixed charge and overhead expense."

The writers maintain that a proper service charge is usually in excess of a simple consumer charge, but much less than the total fixed charges and overhead expenses. They have developed principles on which the service charge may fairly be computed, as indicated in two examples appearing at the end of this discussion. The service charge is based on the assumption that a company stands ready, under certain expense, to do a service or sell a commodity for which no purchaser may materialize. Insofar as it is compelled to do so or is reasonably in danger of having to do so, the company is undoubtly entitled to financial remuneration and to have its financial position insured.

It is not a fixed condition that may be applied empirically to all plants, but exists between two limitations which may be designated as the maximum service charge, where the plant stands ready to deliver and no water is taken, and the minimum service charge where the size, diversity, and variety of consumers maintain practically a constant demand on the plant.

It is assumed that in order to warrant any service charge, it must be shown that the conditions on which it is based actually exist. It must be a real condition and not based on any theory of what might or could happen. It must be based on common sense and actual facts developed from the operating conditions of the plant in question.

The full or maximum service charge may be outlined as that of a plant fully manned, with reservoirs full and pipe lines under pressure running at a rate just sufficient to offset leakage losses, but with no one taking water. The minimum service charge may be conceived as in a plant whose customers maintain a constant cycle of demands on the plant and where there is no loss due to standing ready to serve.

A typical example of the maximum service charge condition would be a plant having one customer taking the entire output, but taking it at such irregular times and in such uncertain quantities that the plant was compelled to keep its entire equipment ready for operation at a moment's notice. The cost to this plant, even when no water whatever was taken, might easily be 90 per cent or more of its full operating cost. The plant in this case is rendering what may be typically designated as a service, as distinguished from the sale of a

commodity. It is, therefore, entitled to remuneration for this service. The service in this case financially predominates over the sale of the commodity.

A representative type of a minimum service charge may be taken as that of a large city plant having, say 100,000 customers, whose varied demands on the plant impose on it practically a fixed cycle of conditions hourly, daily, weekly and seasonally. Such a plant is usually so designed that it is practically at no actual expense on account of standing ready to serve a commodity for which there is no purchaser. Its function is the sale of a commodity, as distinguished from the readiness to sell. Practically speaking, the maximum loss directly imposed by failure of a purchaser is the loss incident to the service line, the meter and the reading and billing. With these determined, they may be designated as a minimum service charge, as distinct on the other extreme from a maximum service charge. The maximum service charge may be considered in its application to a certain large city plant where the average rate for water is about 15 cents per thousand gallons and serves about 100,000 customers. If the theory of the service charge be carried to its logical sequence and it is assumed that all customers withdraw their patronage, the expense of this plant would still be over 90 per cent of its active operating cost. If this 90 per cent were provided for in a service charge, the price of the water would be about 1½ cents per thousand gallons, with the result that the plant would be on a flat rate basis and meters would be of no practical value. As a matter of fact, this plant (aside from fire protection) is not primarily in the business of furnishing a service but of selling a commodity. It suffers practically no financial risk or possible embarrassment from standing ready to serve. It does lose the interest and maintenance on the meter in addition to the billing charges, when the customer fails to buy and is entitled to collect for this in the event of the customer's failure. The two extremes in the type of plant have been taken to show the wide possible range of a service charge designed to meet the financial risk imposed on a plant in standing ready to serve. At one extreme, the service cost takes precedence over the commodity charge and amounts to practically the whole bill. In the other instance, the commodity charge takes precedence and nearly absorbs the service charge. The range of possibilities between these two extremes is infinite.

In the case of the Consolidated Ice Company vs. the City of Pittsburgh, it was necessary, in the interests of the city, to combat a theory which developed a high service charge and a low commodity charge, and we quote from the testimony of Mr. Finley in that case as follows:

> To maintain this condition in the Pittsburgh Plant, even if no water were sold, means the pumping of about fifteen billion gallons per year to keep the plant full. The cost of supplying these fifteen billion gallons, instead of the forty-five billions now handled, would be a large percentage of the present cost, substantially the entire cost except as follows: the saving due to not pumping the thirty billion gallons which the consumers now use would be about $350,000.00 (out of a total annual burden of about $2,650,000) and the ready to serve charge would be the total cost of production less this $350,000.00. If now the suggested method of allocating this charge according to the suggested basis in fixed quantities against the consumers is adopted and the $350,000.00 is allocated amongst the consumers according to the amount of water used, then to all practical intents and purposes, the city is back again on a flat rate assessment basis, except for the fact that consumer, in addition to the fixed amount laid up against him, would pay something over one cent a thousand gallons for the water consumed. This means that the entire economic value of metering would disappear. There would be no check on the waste of water, no personal interest on the consumers part to eliminate waste and the unnecessary outlay of capital in order to handle this waste would then obtain. . . . . If the art of supplying water to large communities is to make any economic progress, and there is no question as to the desirability of this end, it must not be defeated by any false rate hypothesis which takes but little account of the amount of water used and virtually harks back to the flat rate theory based on what might, or could, or should be demanded of the plant. The water meter is the instrument by which great advance in the economy of the art is to be effected. It introduces the element of self-interest in the relation of the consumer to the producer and produces a result which no amount of inspection, argument or propaganda can accomplish. It shows on its dial just what has happened to the plant regardless of the value of any orifice and what it might or might not have demanded. It reveals the big consumer and the little consumer in their true relations and it is not surprising that many rate schemes have been developed, the purpose of which has been to defeat the objects of metering and to escape the responsibility of paying in accordance with the meter readings. Any such rate scheme which submerges the retarding influence of the meter, on waste water, smothers the greatest opportunity for economic advancement available at the present day in the art of supplying water.

A proposed method for distribution of the burden. The usual assumptions underlying the construction of rates are that the total revenue to be derived may be divided into three broad classifications, which roughly correspond to the costs. These are the

consumer, demand and output costs. The consumer costs are taken as those costs (actually derived from a study of the company's books) which cover the reading of meters and billing of charges, book-keeping costs, stationery and those costs which have no reference to the quantity of water used by the consumer, but which are practically the same for each consumer regardless of size.

The demand charge in bulk is assumed to cover such costs as have to do with the possible peak load demands on the plant, such as fires or sudden large momentary uses of water. Since the investment in nearly all elements of the plant including the distribution system is necessarily much greater in order to care for peak loads, than would be true for uniform, non-fluctuating loads, it has usually been assumed that all charges connected with investment, such as interest charges, are included in this category. A portion of the time of certain executive officers is also thought of as being properly chargeable to this account. Having determined the bulk figure, the distribution to the individual consumers is usually effected by finding the total "capacity" of the individual consumers, on the assumption that the area of the service lines or meters supplying the property is a fair measure of the demand which the consumer may make upon the system. When this individual capacity charge is found, it is usually combined with the "consumer charge" in order to form a "service charge" usually based on the size of meter. In practice, the strict application of the theory is usually *considerably* modified by the introduction of a more or less arbitrary diversity factor.

The "output charge" covers such costs as fuel, labor of station employees, chemicals, etc., and varies strictly with the quantity of water pumped. The larger the pumpage the lower this unit cost.

There is little dispute as to the fact that these three general classes of costs do apply in a water works plant. The only divergence of opinion would arise as to their derivation and constitution, and as to their equitable distribution in a rate schedule when once determined. It is in the desire to stimulate further discussion of this problem and in the hope that ultimately a more-or-less standardized method of procedure may be derived and agreed upon that this discussion has been undertaken.

When the foregoing premises are examined, little objection can be suggested to the methods employed in arriving at or in distributing the "consumer" or the "output charge." When the "demand

charge" is similarly examined, however, some of the present methods appear open to question on both counts. It may as well be conceded at this point that no hard and fast rule may be employed in the making of the final rate. Considerations other than those dictated by pure theory must often times be consulted in arriving at the final determination. The making of a rate involves judgments of a judicial character. Questions of expediency often modify the rate derived from a disinterested study of the conditions at the plant. However, in the building of the rate it will probably be conceded that reasonable assumptions corresponding as closely as possible to the known conditions of the plant should be employed. There are several premises in the methods used in deriving and distributing the "demand charge" which appear to the writers not to correspond with the ordinary observable conditions of plant operation.

What are these conditions which are common to all plants and are a matter of every day acceptance in their operation? As to the physical aspects they are essentially these: The plant at a given time furnishes an average daily quantity of water which remains fairly constant from year to year. There is, however, a very wide variation in the consumption during any one day, the minimum being at night and the maximum usually about 10:00 a.m. There is also a seasonal variation; the summer demands and the winter peaks usually exceeding considerably the average consumption. Finally, each plant recognizes the possibility of a set of circumstances which may put a very heavy demand on the plant for a brief period. In addition to these considerations there is always the opportunity that the plant may be called upon to supply water for a heavy conflagration.

On the back-of-the-counter side of the water works office there is another factor which can be counted upon with the same degree of certainty as the average annual consumption. This is the assurance, built up during a long association with the conditions of water works practice, that the consumers can be depended upon to continue their use of water, and, consequently, that the money will come over the counter in a fairly uniform stream from year to year, the growth of the population being taken into consideration.

These are well understood characteristics which are common to the personalities of all plants. In the casting of many rates these conditions have not had an opportunity to be reflected, but have been replaced by theoretical assumptions which do not correspond with the facts.

The justification for the service charge, as advanced by its advocates, starts with the idea that the utility must meet certain fixed and administrative charges whether water is delivered to the consumers or not. It is implied, therefore, that there should be a certain stated charge made against each consumer over and above the charge for water and which will apply whether any water is used or not. This idea seems to be entirely reasonable, when properly applied, because there are certain investment charges against his specific installation for which the utility should receive adequate return in the rates secured from him, and which conceivably a charge against consumption alone would not always cover. The strict application of the usual theory would build up, however, such a large service charge as to make this portion of the consumer's bill the largest item, in the case of the majority of consumers. This would be true, because in the ordinary case most of the fixed charges are thrown into this item. After the fire protection charge to the City (which is chargeable against this item) is taken out, the amount still levied upon the consumer is high.

The fallacy in this premise, as it appears to the writers, lies in the assumption that the whole of the fixed charges should be placed into the demand classification. This idea neglects the obvious fact that the plant is constructed not only for a large demand but primarily for day to day service to consumers. Furthermore the habits of the consumers are fairly well established and quite constant. The assumption that they as a body will suddenly cease to use water is strictly opposed to the facts. The revenue, however the rate is formed, has the habit of coming into the office with due regularity.

All that the utility can reasonably expect is that a sufficient charge in the form of a service rate be assessed against the consumer as will cover the legitimate costs of investment assessable against him, so that if for some reason, such as absence on vacations, his consumption becomes abnormally low, there will still be enough revenue derived to carry his account.

To point out other apparent defects in the present theory and to suggest possible remedies, it will be necessary to enter into a discussion of some of the details of rate making. Admitting that the element of judgment must enter into the determination of the form of the rate finally adopted, yet it certainly will be desirable to fix limits within which this function may operate. In order to fix the lower limit it will be convenient to inquire as to what would be the minimum investment required for supplying the water to consumers.

It is obvious that the absolute minimum investment would be the one in that plant which would be required to work regularly, uniformly and continuously for 24 hours per day, 365 days per year, delivering the total required quantity, but uniformly and not as at present—as demanded. Such a condition might be conceived if each consumer were thought of as having a storage tank which would equalize all of his fluctuations and into which the utility would deliver water at a uniform rate. Obviously the plant investment for this arrangement would be much less than for the plants actually erected, and this condition would extend from the pumps to the filters, buildings and distribution system and would include some reduction even in the size of the consumer's meter and soemtimes his service line. This would be the absolute minimum for a plant which would render average day to day service. It is our belief that at least this much of the investment (and probably more) will be required for ordinary service. The utility could not get along with less.

If this be granted and if it is also conceded that the principal reason for the existence of the plant at all is the serving of the daily needs of the consumer, *it would seem that this much at least* of the fixed charges on the plant investment *is chargeable directly against the consumption,* since in such a plant the summation of all consumptions (or total annual consumption), when divided into the total fixed charges, would represent the price per unit which, when applied to the consumption of each consumer, would fix the proportion of the whole cost which he should bear. This charge then is strictly proportional to the actual average consumption. Contrary to the usual practice then, it would seem that *this cost should be made a part of the output charge,* which is made on the basis of actual consumption of water.

A good example of a minimum plant, as regards the water supply element in plant investment, would be a gravity supply with a reservoir large enough to supply all deficiencies in stream flow. Any hourly or day-to-day fluctuations in load would affect such a large reservoir not at all. The same reservoir would be required whether the consumptions were uniform or fluctuating and the fixed charges against a storage reservoir would therefore appear entirely in the output charge.

Having now allocated to output charge certain elements of cost, which in the past have been considered as applicable to demand and have been made up into the service charge, there remain certain

costs which admittedly should be included under the demand heading. A suggested method of dealing with these costs will now be discussed.

The method proposed is that of splitting up the plant investment into various categories representing like service, such as pumping station and accessories, filtration plant, reservoirs, carrying mains, gridiron distribution system and services and meters. Having accomplished this, the next step involves a study of the probable relation between the normal use and the maximum demand on each element. This may best be illustrated by example. An examination of the pumpage record of the plant is made and the average daily pumpage determined, as is also the maximum hour's pumpage at any time during the year. If a record of pumpage during a heavy fire can be found this is also recorded, or else the maximum pumpage possibilities of the plant used. Assume that the results are as follows:

	Gallons
Average daily pumpage rate	1,000,000
Maximum hourly pumpage rate	2,000,000
Fire	2,500,000

then for convenience the investment costs woud be broken up as follows: 1/2.5 to output charge, (2-1)/2.5 to demand charge and (2.5–2)/2.5 to fire protection service. A little consideration of the activities of the average water works plant will indicate that there may be and usually is a wide variation between the demands of the various elements of the plant. These will also vary with the size of the plant, the larger the plant the smaller the variation. The greatest fluctuations will occur the nearer the consumer is approached. The diversity factor or ironing out effect becomes more pronounced the nearer to the source of supply. It is practically impossible and really unnecessary to determine the actual demand of each consumer, but it will be sufficiently accurate to consider the different classes of consumers based on the sizes of their meters. As a measure of the demands of various consumers we have employed the study of this subject as made by the committee on meter rates for the New England Water Works Association which appears in the December issue of the 1916 JOURNAL. The entire fixed charges on all meters is first allocated to the various groups of meters and the amount to output and to demand fixed by reference to the relation between average use and maximum demand. It is assumed for convenience that the investment in an "average" meter and the

actual meter in use (which is large enough to supply the maximum demand) will be proportional to the demands in each case. The cost of repairs to meters probably bears a close relationship to the investment in meters and this cost is distributed between the classes of meters in proportion to the investment.

A fair basis for distributing the costs of the gridiron system is next sought. It is believed that the fairest basis is that found by assigning the costs directly on the basis of the total number of consumers. A more or less arbitrary distinction must be made between carrying mains and gridiron system, the former representing in this discussion the large arteries emanating from the plant which carry water out to distant districts and to which the smaller mains connect to distribute the water to the consumers themselves.

The size of the gridiron lines is largely dictated by friction loss considerations, it being necessary for the lines to be large enough to furnish fire streams without undue pressure loss. The mileage in these mains has little reference to actual or relative consumptions, but they are made necessary by the fact that the population lives in homes that are scattered over a wide area, and by whose properties water lines must be laid in order to render service. The investment in these lines varies more nearly with the population than with consumption, as such, and it seems fair then to consider that the investment in gridiron system is the same for each consumer. That it probably does not vary with consumption directly might be seen if it were assumed that in a given plant one large industrial consumer, located near the plant, used as much water as all of the remaining population, yet this fact would make little difference in the mileage of mains; they would be required in any event in order to supply the remaining consumers. Any increase in consumers involving building up of new territory would require proportionately greater mileage.

In the distribution of this burden the fire protection charge would ordinarily take the largest share of the cost, and the distribution of the remaining costs between "output" and "demand" would be made with reference to actually observed demands on various parts of the system where records were available. The further distribution between individual classes of consumers would have to be a question of judgment, but the limits would probably be fairly well defined. The tabulation at the end of this paper, in which a complete example is worked out, will explain the method in greater detail. The ratios for each division having been obtained by obser-

vation of actual conditions for this plant, these changes are distributed among the different classes of consumers by methods similar to that for meters.

The consumptions of the various classes of consumers are probably the best basis upon which to distribute the fixed charges on carrying mains, after a figure has been arrived at for charge to fire protection. In a majority of cities the consumption, both large and small, may be distributed at various, widely scattered locations throughout the city. The carrying mains must be large enough to supply these maximum collective demands or consumptions.

Since the quantity of water to be delivered at various controlling areas, not necessarily influenced by distance alone, is the basis for the design of the carrying mains, it would appear that the money that went into its construction would bear a closer relation to the consumption than to any other feature. The ratio between the average daily use and the maximum demand becomes less as the source of supply is approached, and the ratios in the carrying mains are less than in the gridiron.

The consumption basis for the distribution of costs has been used in each of the remaining classes of service with the exception of "consumer costs," where such items as book-keeping, billing, reading meters, etc., have been distributed directly in proportion to the total number of consumers, and the result carried into the sum which later forms the "service charge."

Having assembled the "demand and "output" charges for all consumers on the same sized meters the average output charge is found by dividing the total output costs by the total annual consumption for that class, and the "service charge" by dividing the corresponding sum by the total number of consumers in that class. It then becomes a relatively simple matter to work out an output curve which will substantially fit the average output figures shown in the computed results.

It is intended that such an analysis as here proposed should serve as a cost study preliminary to the administrative decision or the adjudication resulting in the final rate schedule. A concrete illustration of the method discussed will be found in the following tabulations: In the first, the conditions are similar to those which are to be found in a plant serving a population of approximately 50,000 people, while in the second a population of approximately 3500 is considered.

Water plant statistics for 1919–1920

CITY	POPULATION	PLANT VALUE	BONDS OUTSTANDING	PLANT VALUATION PER CAPITA	OPERATING COSTS	OPERATING COSTS PER CAPITA	NUMBER CONSUMERS	OPERATING COST PER CONSUMER	MILLION GALLONS DAILY	OPERATING COST PER MILLION GALLONS
Cleveland	990,000	$28,000,000	12,000,000	$28.39	$953,936	$0.97	108,702	$8.75	127	$20.50
Toledo	260,000	12,500,000	1,915,000	48.00	382,335	1.47	45,500	8.40	28	37.30
Buffalo	510,000	19,198,490	12,847,492	37.60	890,948	1.74	76,258	11.70	136	18.00
Akron	160,000	10,000,000	9,000,000	62.50	267,000	1.67	32,000	8.35	20	36.50
Milwaukee	500,000	10,000,000	195,000	20.00	458,973	.92	66,422	6.92	61.9	20.40
St. Paul	250,000	7,443,707	2,407,000	29.75	247,722	.99	46,000	5.40	17.6	38.60
Youngstown	132,000	2,610,887	763,200	19.75	276,294	2.09	21,169	13.00	12	63.00
Toronto	499,276	16,000,000	16,209,316	32.00	1,150,599	2.30	104,766	11.00	75	42.00
Syracuse	171,000	15,000,000	4,105,000	88.00	249,395	1.45	25,450	10.00	27.5	25.00
Detroit	1,108,735	23,583,428	2,855,114	21.20	1,159,333	1.05	164,779	7.40	152	21.00
Sandusky	30,000				60,615	2.00	5,600	10.80	4	41.50
Indianapolis	267,000	10,000,000	*Private*	37.50			46,080		29	
Albany	112,568	3,099,000	1,520,850	27.50	360,100	3.22	20,674	17.40	20	49.30
Rochester	295,850	13,800,000	10,445,000	46.70	867,000	2.92	49,484	17.50	25	95.00
Canton	90,000	3,000,000	1,500,000	33.30			22,000		13	
Pittsburgh	547,000	32,000,000	10,698,392	58.50	1,422,762	2.60	91,617	15.50	118.4	32.83
Duluth	98,000	3,650,776	2,424,000	37.20	98,587	1.20	13,401	7.35	9	37.20
Harrisburg	76,917								9.1	
Totals	6,098,348	209,886,288	88,885,364		8,845,599		939,902		884.5	
Average (to here)				39.24		1.88		10.10		38.07
Erie	110,000	3,755,000		34.10	263,589	2.30	19,000	13.35	20.4	34.80
Minneapolis	300,000	11,000,000	1,750,000	33.30			61,000		27.5	
Williamsport	45,000	1,600,000	*Private*	35.50	77,141	1.71	11,000	7.00	8.5	24.86

Hypothetical Water Company, 50,000 population, apportionment of charges

		METER SIZES								TOTAL
		¾ inch	¾ inch	1 inch	1¼ and 1½ inch	2 inches	3 inches	4 inches	6 inches	
Number of consumers		7,750	840	379	69	68	27	17	12	9,162
Number of meters		7,817	846	383	74	75	32	20	14	9,261
Annual consumption—Mil. Gals		414	114	125	54	118	208	248	348	1,629
Average consumption per meter—gallons		53,000	135,000	327,000	730,000	1,575,000	6,500,000	12,400,000	24,900,000	163,000
Fixed charge on meters	$13,417	$10,500	$154	$910	$217	$343	$287	$362	$64	$13,417
Ratios: Output 38, demand 134, Fire 0		116/705	580/1200	1700/2050	11/35	55/76	111/139	20/40	9/13	
—Distribution to output		$1,728	$75	$755	$161	$249	$207	180	445	$3,800
x Distribution to demand		8,772	79	155	56	94	80	182	199	9,617
xRepairs to meters—demand	$16,000	$12,525	$183	$1,085	$259	$408	$342	$431	$767	$16,000
Fixed charge on gridiron	$32,165									
Output and demand		$13,070	$1,414	$640	$116	$115	$46	$29	$20	$15,450
—Output		6,870	832	426	78	77	30	20	14	8,347
xDemand		6,200	582	214	38	38	16	9	6	7,103
oFire										1,6715
Fixed—reservoirs and supply lines	$50,590									
Output and demand		$8,990	$2,470	$2,710	$1,175	$2,560	$4,510	$5,380	$7,545	$35,340
—Output		4,495	$,370	1,690	840	1,830	3,220	3,850	5,380	22,675
xDemand		4,495	1,100	1,020	335	730	1,290	1,530	2,165	12,665
oFire										15,250
Fixed—pumping and filters	$57,130									
Output and demand		$13,065	$3,600	$3,950	$1,705	$3,725	$6,570	$7,830	$10,972	$51,417
—Output		9,320	2,400	2,820	1,310	3,100	5,480	6,530	9,140	40,100
xDemand		3,745	1,200	1,130	395	625	1,090	1,300	1,832	11,317
oFire										5,713

xBilling, collecting, etc	$14,920	$12,590	$1,365	$617	$120	$121	$52	$32	$23	$14,920
—Operating expense	$116,400	$29,550	$8,150	$8,930	$3,860	$8,430	$14,880	$17,720	$24,880	$116,400
Totals:—										
oFire	$37,678									
xService	$71,622	$48,327	$4,509	$4,221	$1,203	$2,016	$2,870	$3,484	$4,992	$71,622
—Output	$191,322	51,963	12,827	14,621	6,249	13,686	23,817	28,300	39,859	191,322
	$300,622	$100,290	$17,336	$18,842	$7,452	$15,702	$26,687	$31,784	$44,851	$262,944
Average price per m. gals		24.2c	15.2c	15.1c	13.8c	13.3c	12.8c	12.8c	12.8c	16.1c
Service		$6.18	$5.33	$11.00	$16.30	$26.90	$90.00	$174.00	$356	$7.73
Output		0.126	0.113	.117	0.116	0.116	9.115	0.114	0.114	0.118
Final rate adopted:										
Service		$6.00	$8.00	$10.00	$13.00	$20.00	$50.00	$100.00	$200.00	$7.17
Straight output charge of		0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

Small Water Company, 3,500 population, apportionment of charges

		METER SIZES						TOTAL
		¾ inch	¾ inch	1 inch	1½ inch and 1½ inch	2 inches	4 inches	
Number of consumers and meters		626	4	9	3	2	1	645
Annual consumption—gallons		14,553,600	508,700	7,194,400	1,957,600	5,887,300	6,871,600	36,973,200
Average consumption per meter—gallons		23,250	127,200	800,000	652,500	2,943,600	6,871,600	57,300
Fixed charge on meters, etc	$1,829	$1,711	$17	$36	$23	$17	$25	$1,829
Ratios—Output 19, Demand 100, Fire 0		116/705	580/1200	1700/2050	11/35	55/76	20/40	19/100
—Distribution to output		$282	$8	$30	$7	$12	$13	$352
x Distribution to demand		1,429	9	6	16	5	12	1,477
xRepairs to meters, etc. (demand)	$328	$307	$3	$6	$4	$3	$5	$328
Fixed charge on gridiron	$5,363							
Output and demand		2,705	$17	$40	$13	$9	$4	$2,788
—Output		1,420	10	27	8	6	2	1,473
xDemand		1,285	7	13	5	3	2	1,315
oFire								2,575
Fixed—on standpipe, force and carrying	$3,850							
Output and demand		$1,062	$37	$523	$143	$428	$502	$2,695
—Output		483	19	291	89	285	358	1,525
xDemand		579	18	232	54	143	144	1,170
oFire								1,155
Fixed—on pumping plant and filters	$8,839							$6,630
Output and demand		$2,608	$92	$1,290	$351	$1,057	$1,232	$6,630
—Output		1,630	58	862	234	755	880	4,419
xDemand		978	34	428	117	302	352	2,211
oFire								2,210

xBilling, collecting, etc.	$2,047	$1,986	$13	$29	$10	$6	$3	$2,047
xAdministration, etc.	3,000	1,763	35	399	112	319	372	3,000
—Operating Expense	$9,399	$3,905	$137	$1,935	$527	$1,585	$1,850	$9,939
oFire	$5,940							$5,940
xDemand service	11,548	88,327	$119	$1,113	$318	$781	$890	11,548
—Output	17,708	7,720	232	3,145	865	2,643	3,103	17,708
	$35,196	16,047	$351	$4,258	$1,183	$3,424	$3,993	$35,196
Average cost per M. gallons		$1.10	$.69	$.59	$.60	$.58	$.58	$.95
Service charge		$13.30	$39.80	$123.80	$106.90	$390.00	$890.00	$17.99
Output		0.53	0.46	0.44	0.44	0.45	0.45	0.48
Final rate = 4000 per quarter at 55 cents								
All over at 45 cents plus service charge of		$15.00	$35.00	$125.00	$200.00	$360.00	$600.00	

THE QUALITY OF WATER AT DIFFERENT POINTS ON A WATER SYSTEM[1]

By Sheppard T. Powell[2]

The quality of water at the point of purification is frequently quite different from the quality of the same water drawn by the consumer from the distribution main. The percentage of increase or decrease in the numbers of bacteria and the B. coli content of the water supply at these different points may be so slight as to excite but little comment either by the health authorities or by the men in charge of the operation of the system. A review of the operating results of thirty-two different municipal water plants showed that in 92 per cent of these systems there was an increase in the number of bacteria from the point of purification to the tap water samples. These increases ranged from about 2 per cent to 500 per cent. In the majority of the systems the increase was slight.

The reason for a change in the quality of the water cannot be accounted for readily in all instances. Local operating conditions and methods of treatment and distribution must be taken into consideration to determine definitely just why the results at different points on a system vary. In specific instances there are radical changes in operation that may result in wide fluctuations from year to year, or from season to season.

A condition of this kind has been noted in The Baltimore County Water and Electric Company's system supplied from the Avalon Filtration Plant. The depreciation in the quality of the water after passing through one of the distribution reservoirs of this Company's system, during the summer months of 1919 and 1920 has been so marked that it necessitated intensive study to definitely determine the causes responsible for the results obtained.

[1] Presented at the Cleveland Convention, June 8, 1921. Discussion of this paper is requested and should be sent to the Editor.

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Before entering into a discussion of these results it is well to describe briefly the Company's water supply system with reference to the method of purification, the distribution system and the reservoir.

The Avalon Plant of this Company was installed about 1900. The method of purification at that time was slow sand filtration without sterilization.

The raw water supply is drawn from the Patapsco River and from Rockburn Branch. The former is subject to considerable pollution and often becomes excessively turbid. The latter is a small spring stream, comparatively clear, which receives little sewage contamination. After purification the water is pumped to Catonsville and other suburban[3] territory adjacent to Baltimore City. The water is pumped first to a 400,000 gallon standpipe which is operated in conjunction with a 4,000,000 gallon reservoir. When the standpipe is filled, the water is by-passed to this reservoir. From here the water is pumped to Mt. Washington, Towson, Lutherville and other towns supplied by the Company.

In 1908 it became necessary to increase the purification facilities and two mechanical filters, having a combined capacity of 1,000,000 gallons per 24 hours, were constructed. From 1908 to 1910 these filters were operated in conjunction with the slow sand plant and gave satisfactory results. In the latter year the water was treated with hypochlorite of lime prior to filtration. In 1916 three filter units were added, giving a total filter capacity from the mechanical filters of 2,500,000 gallons per day.

During the summer of 1919 it was noted that there was a marked increase of the number of B. coli and of the total bacterial count in the tap waters from one portion of the Company's distribution system.

Mr. Morse, Chief Engineer of the State Department of Health of Maryland, suggested that the chlorine dose be split, applying a portion of the chemical before filtration, with a secondary dose after the water had passed through the mechanical filters. This was done and at the same time a record was kept of the residual chlorine in the filtered water at the filtration plant. Although the dose of chlorine was steadily increased there was no improvement in the quality of the water drawn from the taps.

Careful study was then undertaken by the Engineering Force of the State Department of Health, the City Bacteriologist, the writer and Dr. Eaton, of the School of Hygiene of Johns Hopkins

[3] A large portion of this territory has been annexed to Baltimore City.

University, who acted as referee becteriologist. The findings of this investigation showed that the poor quality of tap water was restricted almost entirely to the territory supplied with water from the distribution reservoir at Catonsville.

As shown in figure 1, the water delivered from the filtration plant, after filtration and chlorination, from 1915 to date, never exceeded a monthly average content of more than 10 bacteria per cubic centimeter, when grown on gelatine at 20°C. The water from the taps prior to passage through the Catonsville reservoir averaged in most instances less than 10 per cubic centimeter, but in 1920, during three months, this average was above 20 per cubic centimeter.

There has always been a slight increase in the bacterial count after the passage of water through the reservoir in question, but during 1919 and 1920 the numbers of bacteria in the reservoir water became very great. This condition was even more marked in the B. coli content of the water, as shown graphically in figure 2. These results have been set forth in comparison with the chlorine applied to the filtered water and the residual chlorine in the treated water at the Avalon Filtration Plant. From these records it is seen clearly that the B. coli content in the tap water was entirely independent of the dose of chlorine or the amount of residual chlorine in the treated water at the point of treatment.

The B. coli content of the tap water samples reached its peak during the summer months, falling off rapidly when cold weather set in. This condition was very marked in the reservoir water.

During the months of June and October, 1920, there was also an increase in the number of B. coli in the tap water, before passage through the reservoir. These two high points can be accounted for by the fact that in these months comparatively few samples were taken, so that a single positive sample in one-tenth of 1 cc. greatly increased the average for the month.

The condition to which we wish to draw attention is that prior to 1919 the B. coli content of the tap waters came well within the United States Treasury Department Standard, while in the summer of 1919 the coli content became excessive after passage through the reservoir, in spite of the fact that the chlorine applied was high. As soon as cold weather set in conditions again became normal. The quality of the water in the summer of 1920 became bad again, and continued so until cold weather appeared.

In attempting to arrive at some explanation for this condition many factors were taken into consideration.

It will be noted, as shown in figure 1, that there was no correlation between the quality of the untreated water and the results of the filtered and tap samples. Also, as shown in figure 3, no correlation could be drawn between the temperatures and the bacterial content of the tap waters, as it will be seen from this figure that the temperature curve is quite uniform from year to year.

The Catonsville reservoir is well protected against any possible chance of sewage contamination. The reservoir, which contains

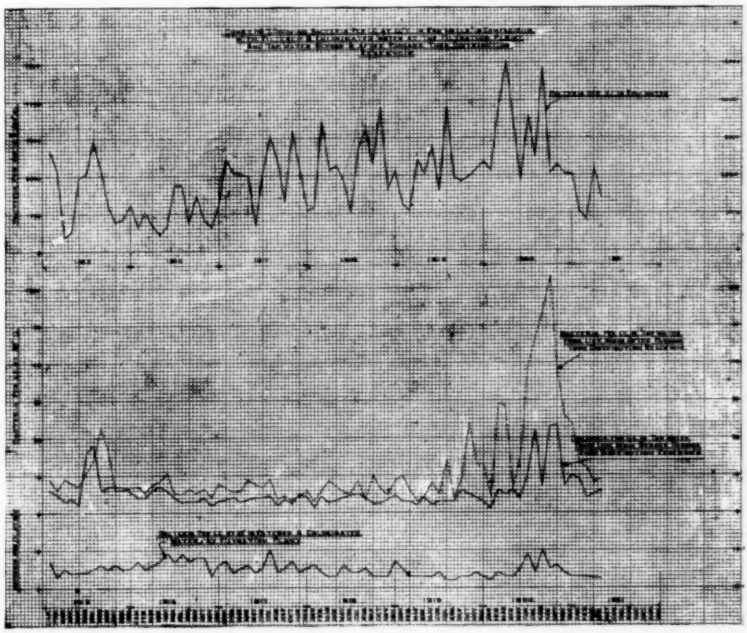

FIG. 1

4,000,000 gallons of water, is surrounded by a bank about 8 feet high and there is a 5-foot fence running around the entire property. During the entire day there is a man on duty at the pumping station and no one is permitted to enter the grounds. The water in the reservoir is several feet higher than the surrounding territory and there has always been leakage from this reservoir. The reservoir is situated in a suburban territory with dwellings 100 or 200 yards away but extreme care has always been exercised to prevent local contamination.

As a result of the study that has been made to determine the cause of the unusual condition that has been noted in this investigation one fact stands out prominently.

Prior to 1919 tadpoles were present in small numbers in the reservoir water. Most of these tadpoles were of the common toad or leopard frog type. No great numbers of tadpoles or bullfrogs were ever noted in this reservoir. It might be well to point out at this time that the tadpoles propagating from the spawn of bullfrogs do not change into frogs in one season but may live in the water for one, two or three years before they reach a frog state. These tadpoles are very large, some of them measuring 6 to 8 inches in length and $1\frac{1}{2}$ to 2 inches in circumference.

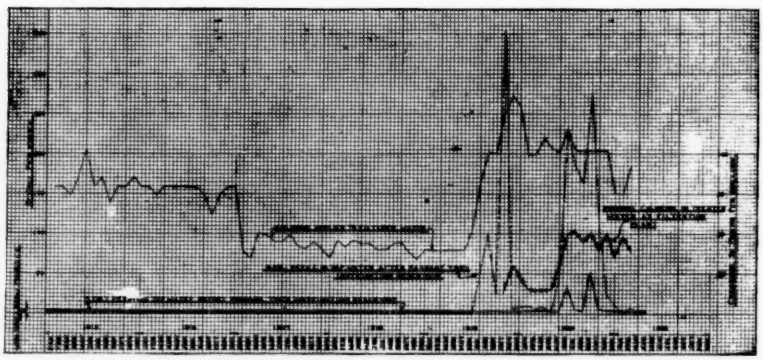

FIG. 2

During the summer of 1919 tadpoles were present in the reservoir in great numbers. It was thought inadvisable to attempt to kill these with copper sulphate, as it required comparatively heavy doses to accomplish this. In addition, it seemed unwise to kill so many of these organisms at one time.

Laboratory experiments were carried on with tadpoles taken from this reservoir and the results proved beyond question that these organisms are capable of giving off great numbers of B. coli. In passing it may be of interest to show to what extent these organisms may contaminate the supply.

Tadpoles were taken and thoroughly washed with sterile water and placed in 1 liter samples of water which had been previously sterilized. Shortly after placing the sterilized tadpoles in water samples were taken and analyzed and in every instance these samples

did not show the presence of B. coli in 0.1, 1 or 10 cc. of water. After one hour's time samples were again taken from the water in which the tadpoles had been placed and B. coli was found in 0.001, 0.01, 0.1 and 1 cc. of the water tested.

A number of other tadpoles were sent to Dr. Salter, Bacteriologist of the State Department of Health of Maryland, who isolated B. coli of a fecal type from the intestines of the tadpoles.

From these findings there is no doubt in the mind of the writer that tadpoles in large numbers in the reservoir water were responsible for the high bacterial content of the water after passing through the Catonsville reservoir.

The question naturally arises as to why this condition did not appear prior to 1919. An explanation of this was difficult until a few weeks ago. After careful questioning of the operator in charge of the pumping station it was learned that prior to that year he had permitted a friend to come to the reservoir at night and hunt frogs. He informed me that not infrequently this man would obtain as many as a dozen large bullfrogs in one night. The removal of the frogs permitted little spawning in the reservoir water. During the spring of 1919 it became known that this practice was being carried on and the man in charge of the plant was ordered to prohibit anyone from entering the reservoir property without permission from the management of the Company.

It is reasonable to suppose, with an excessive B. coli content in the water, provided these organisms were due to failure of the purification system or from sewage contamination, that this condition would be reflected in the typhoid fever case rate in the territory supplied with the filtered and sterilized water. To determine this fact the typhoid fever case rates for Baltimore County have been plotted and are given in figure 3. The number of cases per 100,000 population is shown in the territory supplied exclusively with filtered water from the Avalon Plant. In addition, the typhoid fever case rates in Baltimore County, exclusive of the territory supplied from Avalon, are shown. It is seen from these curves that the typhoid fever rates in Baltimore County in these two territories follow each other very closely, indicating apparently no correlation between the character of the water and the typhoid fever.

In addition to these facts the curves show that in the period in which the greatest number of B. coli were reported in the filtered

water the typhoid fever in the territory supplied with this water was extremely low.

Attention is directed also to the fact that prior to 1919, when the bacteriological quality of the water from the reservoir met the United States Treasury Department Standard, the prevalence of typhoid fever in this territory was much greater than when the quality of the water was poor.

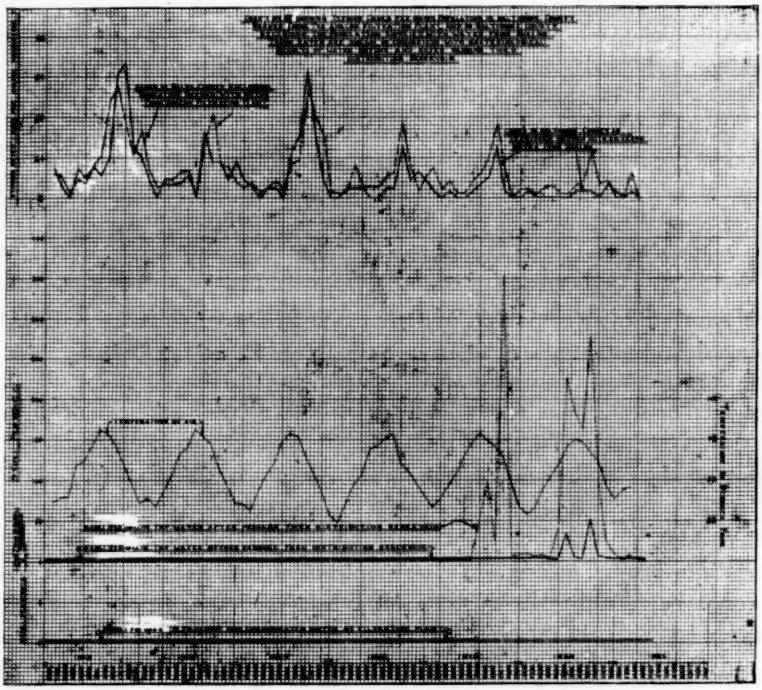

FIG. 3

In plotting these results the typhoid fever case rate has been used instead of the mortality rate. Owing to the proximity of this territory to the city, serious cases which might result fatally are often taken to the city hospitals and in case of death the mortality would be reported in the city and not in the county.

Several interesting problems present themselves as a result of this investigation. It is of primary interest to note the effect of an uncovered filtered water reservoir upon the bacteriological quality of the supply, which furnishes no small argument in favor of covering

such reservoirs. Of no less interest is the interpretation of these bacterial data in judging the potability of the supply. The presence of the colon group isolated in large numbers from water indicates contamination of questionable character. In this investigation the water after passage through the Catonsville reservoir contained at times high colon content, but it was clearly evident that this was not contamination other than from tadpoles or possibly from birds. It demonstrates the inadequacy of our present bacteriological methods in indicating the true quality of a supply.

OVERCOMING DIFFICULTIES WITH CRUSTACEA IN FILTER BEDS[1]

By Helman Rosenthal[2]

The Dallas water purification plant receives its water from either of two sources. Elm Fork of the Trinity River is the more common one, but during the last two years we have received about 40 per cent of our raw water from Bachman's Lake, an artificial reservoir holding about 700,000,000 gallons of water. The water from this reservoir, which comes from natural springs and a small drainage area, is nearly always clear. Its turbidity for a long time may be only one part per million. It is comparatively hard, about 150 parts per million, mostly bicarbonate alkalinity. This water is easily treated. However, at times this water carries a small flea about $\frac{1}{32}$ inch long. Although the raw water has only a few, the water reaching the filters is at times full of them. They multiply very rapidly, and at times become so thick as to actually interfere with filtration. Washing the filters is only a temporary relief. Sometimes they even work their way through the filters.

A study of the organism under the microscope showed the following characteristics. It is a long organism which swims on its belly. It has a very active tail, which moves up and down at "high speed." It has long legs, those in front being as long as the body. These legs have about 15 to 18 definite joints and small branches like thorns on a rose twig. The flea seems to accomplish most of its swimming with these legs and tail. It has a sort of opal looking eye, which at times seems to be of a ruby red color. It has about 8 legs, resembling fins of a fish. When the drop, in which the examination was made, was almost gone by evaporation, the organism put up a struggle, and part of its head turned blood red, as if wounded.

[1] Presented at the Cleveland Convention, June 8, 1921. Discussion is invited and should be sent to the Editor.

[2] Superintendent and Chief Chemist, Water Purification Plant, Dallas, Texas.

Its tail resembles that of a fish, the part nearest the body is one narrow unit and it becomes fan shaped with about 10 or 12 ribs. It has a sort of elongated transparent protoplasmic movement from head to tail which terminates in a yellowish brown sack.

Some of these animalculae, which I presume are the females, have a sack hanging right under the tail. This sack contains about a dozen pea shaped cells. Each of these have myriads of nuclei in them. Upon breaking up some of these cells innumerable nuclei spread in all directions. It is undoubtedly a Crustacea organism and is similar to, or perhaps the same as, the *Diaptomus copepoda.*

As stated previously, this organism at times becomes a real nuisance, and a method had to be devised to rid the filters of the pest. Although CuSo4 suggested itself, its use was somewhat expensive, nor was it very desirable. Finally the writer hit on an idea of chlorinating the water just before it goes to the filters. We always chlorinate the water after filtration using about 0.2 to 0.4 part per million of liquid chlorine. We used therefore from 0.5 to 0.7 part per million of liquid chlorine before filtration. About three hours later samples of water from the filters showed the total absence of these organisms.

The writer feared that the strong chlorine solution might harm the biological activity going on within the filters, but the bacterial reduction showed that the fear was groundless.

The total expense was small indeed and considerably less than copper sulfate would have cost and, of course, not in the least objectionable.

REPORT OF THE COMMITTEE ON OFFICIAL STANDARDS OF WATER ANALYSIS[1]

Your Committee on Official Standards of Water Analysis, which was continued from last year, begs to report that, in view of the action of the Association at the Montreal Convention in forming a Council on Standardization, and in view of the fact that the functions of this Committee should logically be assumed by the newly-created body, the present committee has not attempted to carry out or to formulate any active program during the past year.

It is recommended that the Committee on Official Standards of Water Analysis be discharged, or made a subordinate committee of the Council on Standardization of the Association and that the Council be specifically charged with assuming the duties and functions formerly associated with the Committee, in addition to the duties and functions already assumed by the Council in accordance with the action of the Association at the Montreal Convention.

Without attempting to dictate any policy to the Council on Standardization, the present committee would suggest that investigations be made of and action taken upon the following matters, which among others, have been brought to the attention of the Committee:

1. Securing coöperation of the Bureau of Chemistry, of the United States Department of Agriculture, the United States Public Health Service, and the authorities of the Dominion of Canada, as well as the American Public Health Association, the American Chemical Society, the Association of Official Agricultural Chemists and the Society of American Bacteriologists in the preparation of methods of analysis which are to be known as the Standard Methods of Water Analysis. The reason for this recommendation is based upon the need for Standard Methods which are legally recognized. Experience in the United States has shown that when a matter of legal acceptance is involved, the methods of analysis in use at Washington in the government laboratories take precedence in a court of law.

[1] Submitted to the Executive Committee, June 8, 1921, and ordered printed in the JOURNAL. Discussion is desired and should be sent to the Editor.

These standards should be supplemented by recommendations, or general suggestions, on the information, other than analytical data, which should be available in order to interpret properly the analytical results and to give a definite opinion on the safety of a water supply.

2. Undertaking a study of the subject of standards for the interpretation of the results of mineral analyses, with the object of making the results more generally available, and of bringing about a more uniform acceptance of a single method of reporting the results, which will more satisfactorily represent the actual condition of the water, and which will take proper cognizance of complex ions, as well as the simple ones.

3. Continuing studies and correlating information on the tests for the organisms of the colon group and related forms. These studies should have reference to such points as:

a. Shortening the time necessary for making B. coli determinations.

b. Attempting to place the enumeration of B. coli in water supplies on a more uniform basis.

c. Determining the actual sanitary importance of certain bacteria which ferment lactose broth, but which are not usually included as B. coli type organisms.

d. Determining the actual sanitary importance of such anaerobes as Clostridium welchii.

e. Determining the actual sanitary significance of certain non-lactrose-fermenting organisms, such as the proteus group or other hydrogen sulphide producing bacteria, whose presence in waters suggests an unclean or unsatisfactory source.

f. Excluding spurious positive tests for organisms of the B. coli group from the reports of water plants by the use of special media, such as brilliant green bile and broth, gentian violet broth, eosin-methylene-blue agar, and other special or differential media, with a view to rendering simpler this important determination.

g. Studying the loading of filters to determine limits within which dependence may be put with safety upon the sufficiency of purification.

4. Considering the use of more satisfactory turbidity standards and apparatus, and the desirability of having silica standards for the turbidity determination prepared by a central authority, such as the United States Bureau of Standards.

5. Investigating the application of routine hydrogen-ion determinations to the control of coagulation in filter plants, where excess alaklinity is always present.

6. Studying the chlorine absorption method of chlorination control, and determining the necessary range of the excess dose of chlorine.

7. Investigating the sanitary importance, if any, of the passage through filters of aluminum compounds, and of the treatment of waters with comparatively large doses of chlorine. It has been suggested that the addition of chlorine to water supplies may be concerned in the apparent rise in nephritis death rates in our cities. This does not seem probable since nephritis rates were rising even before 1908 when hypochlorite was generally introduced, and in view of the fact that rates for the rural districts seem to be rising also.

Respectfully submitted,

M. H. McCrady,
E. M. Chamot,
H. A. Whittaker,
Abel Wolman,
Jack J. Hinman, Jr.
Chairman.

REPORT OF THE COUNCIL ON STANDARDIZATION[1]

The Council on Standardization which was established by the Association at Montreal in 1920, has been outlining its work by conference and by correspondence. It has considered it much better to develop a working program, which is flexible, yet comprehensive, rather than to have appointed at once a large number of committees without well-defined purposes and with personnel selected without the full consideration desirable. It has been certain from the outset that no program should be laid out which cannot be followed by committees with individual resources at the command of their members, by the help the Association can give, and by the assistance that reasonably can be expected from other sources.

In general, the committees will find it useful to function in two ways. The first is to carry on actual investigations, which may not furnish much information except at intervals. The second is to prepare for publication in the JOURNAL brief abstracts of the reports and papers on current developments of importance to the members. The publication of such abstracts can be made of high educational value, and their preparation is an excellent way to secure the coöperation of some of the younger members in committee work. It is suggested that the Association should compensate the members who do this work at the rate of about half a cent a word for the abstracts as printed. For some years it is probable that this abstracting of information will be the most productive educational feature of the Council's work.

It is expected that each Committee will first lay out a program for carrying on the work assigned to it, and will then take up this program with the Council. When it has been developed to the satisfaction of the Council, the latter will take steps to gain for it the support of the Association. The Council believes that "practical" committee work should be carried along simultaneously with research, so that water works operators will get the maximum possible benefit as early as practicable from the Council's activities. Furthermore, this program will make it practicable for each committee to carry its work forward in the speediest way to the point where the

[1]Submitted to the Executive Committee, June 8, 1921, and ordered printed in the JOURNAL. Discussion is desired and should be sent to the Editor.

experience of the practical waterworks men can be drawn upon in order to couple theory and practice in the most helpful way. In this manner a large number of our members will be joining coöperatively in improving water works practice.

The Council has held conferences here at Cleveland and has reached the conclusion that the committee work outlined in the attached program should be undertaken. In order to carry it on properly, the Council has asked the Finance Committee to place $2000 to its credit in the 1921–1922 budget.

The Council regards itself as a Committee on Committees for those subjects which involve standardization matters. It will be the committees and not the Council which shall be given the credit for actual performances, while to the Council will fall the task of coördinating and stimulating actions along practical lines and of avoiding duplication of effort. It is not to be expected that each committee will produce, year by year, reports of great importance, but it is hoped that all committees will put before the membership concrete statements of progress made in their respective fields expressed in such a manner as to be readily understood by those interested in a practical way in these subjects.

To get the abstracts under way a committee consisting of A. L. Fales, J. N. Chester, F. C. Jordan, R. S. Weston and A. Wolman has been appointed to report to the Council by September 15, 1921.

It is understood by the Council that such portion of the funds to be reserved for its use as will not be actually necessary will be available for other activities authorized in the Association budget for the year 1921–1922.

Attached are the topics and personnel[2] of the committees which have been established with the understanding that each committee has the authority to extend its personnel as it deems necessary.

Mr. Malcolm Pirnie of Hazen, Whipple & Fuller, 30 East 42d street, New York, has kindly consented to act as secretary of the Council.

GEORGE W. FULLER, CHAIRMAN,
FRANK A. BARBOUR,
EDWARD BARTOW,
GEORGE A. JOHNSON,
GEORGE C. WHIPPLE,
Council on Standardization.

[2] See Supplement to the JOURNAL, September, 1921, for the list.

REPORT OF THE COMMITTEE ON ABSTRACTS TO THE COUNCIL ON STANDARDIZATION

Your Committee on Abstracts held a meeting in Cleveland on June 8, at which time the work of the Committee was outlined and discussed. Professor Bartow, President of the Association, and Mr. Pirnie, Secretary of the Council, were present and offered valuable suggestions. The chairman was instructed by the Committee to submit our plans to your Council for approval.

It is proposed to include in the list of publications for abstracts, all of the American periodicals likely to contain information of value to the water works men, proceedings of kindred societies, United States Government, state and municipal reports, bulletins and papers, public utilities reports, and university or college bulletins.

It is not the intention to abstract the chemical and bacteriological journals which are already being abstracted by the American Chemical Society and the abstracts pubished in *Chemical Abstracts*, under the division of "Water, Sewage and Sanitation." It is, however, proposed to communicate with the officials of the American Chemical Society, with a view to utilizing such of their abstracts as are of interest to the water works men. It is desired not only to avoid duplication of work in abstracting, but to utilize any work already being done in this line.

Your Committee on Abstracts feels that at the outset the publications examined regularly should be confined to the United States and Canada, although we see no objection to including abstracts of articles of special importance, from foreign journals, which may come to the attention of the abstractors, if it be clearly indicated in the Journal that such abstracting of foreign journals is at present the exception rather than the rule. Eventually, we should hope that the regular abstracting would include all important foreign publications, in addition to those in United States and Canada. We believe that a list of the periodicals abstracted, should appear in the first issue of the JOURNAL containing abstracts, and periodically thereafter.

We are of the opinion that the abstracting of American publications should be as complete as possible and that in cases where the

publication of abstracts is not warranted at the present time, references at least should be given so that we may have at the outset a complete bibliography of articles of interest to water works men.

We propose to start the abstracting with the publications issued subsequent to June 30, 1921, and to have the first of these in the hands of your Secretary before the 15th of September next, so that they may appear in the January issue of the JOURNAL. The list of publications for abstracting has been divided among the members of the Committee, each member being responsible for the abstracting of the periodicals assigned to him. We understand it is not expected that the members of the Committee on Abstracts will necessarily do any abstracting, but that they will determine the articles to be abstracted and delegate the abstracting not done by themselves, to the appropriate committee, under the jurisdiction of the Council, the abstracts so prepared to be sent directly to the secretary of the Council.

In order to facilitate the work of our Committee on Abstracts, we suggest that you send a copy of the report of your Council, which was adopted by the Association, to each of the committee chairmen, with a letter explaining in detail the duties of his committee and the function of the Committee on Abstracts.

We enclose the list of periodicals[1] to be examined for abstracts, as now assigned to the members of the Committee. This list is not yet complete and we shall be glad to add such publications as may be suggested by your Council and its various committees.

Respectfully yours,

A. L. FALES, *Chairman*
J. N. CHESTER,
F. C. JORDAN,
R. S. WESTON,
A. WOLMAN.

[1]The list appears in Supplement to JOURNAL, September, 1921.

ANNUAL REPORT OF THE TREASURER

Permit me to submit my report as Treasurer of the American Water Works Association for the year ending March 31, 1921.

The funds of the Association are on deposit with the Troy Trust Company, Troy, N. Y., as per order of the Finance Committee.

The receipts during the year were as follows:	
Balance, April 1, 1920	$2,392.52
Received from J. M. Diven, Secretary	13,327.67
Interest on deposits	76.49
Interest on investments	530.00
Total	$16,326.68
Disbursements as per vouchers, cancelled, checks and debit slips	16,091.94
Balance, April 1, 1921	$234.74

Attached you will find certificate of the Troy Trust Company, showing a deposit of $578.24 at the close of business March 31, 1921.

From this balance there should be deducted the following for unreturned checks.

Deposit as per certificate		$578.24
Unreturned checks:		
V1087–Ck 1087 John M. Goodell	$200.00	
V1091–Ck 1091 Flannigan-Pearson Co.	10.50	
V1092–Ck 1092 John M. Goodell	100.00	
V1097–Ck 1097 H. G. Hunter	33.00	343.50
Balance, April 1, 1921		$234.74

The receipted vouchers, cancelled checks and debit slips, with the book of the Treasurer, are submitted for audit.

The Permanent Fund now consists of the following:

4½ $1,000 Dominion of Canada 15 yrs. 5% Bonds	$4,000.00
4- 500 U. S. Liberty 1st., 3½% Bonds	2,000.00
1–1,000 U. S. Liberty 2nd., 4¼% Bond	1,000.00
2–1,000 U. S. Liberty 3rd., 4¼% Bonds	2,000.00
2–1,000 U. S. Liberty 4th., 4¼% Bonds	2,000.00
1–1,000 U. S. Victory, 4¾% Bond	1,000.00
Par value of Permanent Fund	$12,000.00

The Treasurer receives no salary and is under $10,000.00 bond as per the order of the Finance Committee.

Respectfully submitted,
JAMES M. CAIRD,
Treasurer.

Troy, N. Y. April 6, 1921.

This is to certify that we have examined the securities submitted by the Treasurer and find the same as stated above.

WILLIAM P. MASON,
JAS. H. CALDWELL,
Committee.

Troy, N. Y., April 1, 1921.

This is to certify that there was to the credit of American Water Works Association at the close of business March 31st 1921, the sum of five hundred and seventy-eight dollars and twenty-four ($578.24) cents, on the books of the Troy Trust Company of Troy, N. Y.

F. BUNCE,
Treasurer.

Permit me to submit the report of the financial condition of the Electrolysis Investigation Fund.

No contributions were received during the past year.

Balance as per statment, April 1, 1920	$1,702.32
Disbursements, as per vouchers and cancelled checks	751.77
Balance, April 1, 1921	$950.55

Attached you will find certificate from the Union National Bank, Troy, N. Y., showing a balance on deposit at the close of business, March 31, 1921, of $950.55.

The book of the Treasurer, together with vouchers and cancelled checks, are submitted for audit.

Respectfully submitted,
JAMES M. CAIRD,
Treasurer.

Balance to the credit of the American Water Works Association on March 31st was $950.55.

UNION NATIONAL BANK,
Joseph E. Kober,
Assistant Cashier.

DISCUSSIONS

POLLUTION OF RIVER WATER IN THE PITTSBURGH DISTRICT[1]

The investigation by the United States Engineer Office of pollution of navigable rivers in the Pittsburgh District was most exhaustive. Through the courtesy of the district engineer, the writer has examined this report in some detail and was amazed to find the amount of information which had been collected. While Mr. Young's paper[1] calls attention to the important features, it is unfortunate that the entire report has not been made available for general use and that no action has been taken as a result of the findings.

The investigation establishes that practically all of the streams and rivers of the Pittsburgh district are seriously polluted by acid wastes, the greater portion of which results from coal mining. This is one of the most important industries responsible for the growth of the district as a steel producing centre. While such a serious condition suggests the pressing need for remedial measures, the remedy cannot be too drastic nor can it impose unnecessary burdens or handicaps. On the other hand, the coal mining industry should not be permitted to continue to handicap all of the water using industries of the district, as it now does, without making any attempt to correct conditions. It is unthinkable that all the coal mines should be compelled to discontinue operations pending a solution of the problem, but now that the conditions are more clearly understood and the difficulties of stream pollution are realized, it would seem proper that the policy adopted by some states, of endeavoring to preserve the present purity of streams or at least to control the degree of pollution, should be adopted nationally.

If this subject is sufficiently important for the federal government to investigate, is it not also of sufficient importance to warrant an attempt to find a remedy? It would seem so to the writer, although he has been informed that several agencies of the government have advised that the problem was not of sufficiently wide occurrence to warrant their attention. It is true that at the present time the prob-

[1] JOURNAL, May, 1921, page 201.

lem is acute only in the intensively developed coal mining and industrial districts. As such centers develop elsewhere, however, this problem also will arise. Since damage in one state may result from pollution introduced into the stream in another state, it appears that only the federal government has sufficient power to effect a remedy.

The health department of the State of Pennsylvania has done some work in an effort to develop a method to remove sulphuric acid and its derivatives from water, but has not published any results. It seems probable that the work will be discontinued in an effort to reduce expenses, although the amount so far spent is small in comparison with the losses suffered by the industries affected. It is hoped that this is not correct, as there have been so few serious attempts made to develop a solution of this problem.

As a result of the investigation described by Mr. Young, a bill was introduced in Congress to protect the steel portions of government locks and dams from corrosion by acid waters, by prohibiting the discharge of acid wastes into navigable streams—surely a drastic remedy which would have been difficult to enforce aside from its economic aspects.

The growth of pollution in the rivers has been so gradual that in many cases it has been accepted as a matter of course and the serious injuries to industries are not fully appreciated. In general, the costs due to the use of bad water appear under such a variety of charges that they are usually lost sight of. The actual cost of treatment is usually the smallest part of the increased cost of using a polluted supply. The most serious objection is that, even after treatment the water is much more difficult to use than a naturally, pure water.

The literature of water supply engineering contains comparatively little reference to standards of quality for industrial supplies. One reason for this is the ineffectiveness of existing methods of treatment to produce a satisfactory industrial water from a seriously polluted source. The writer called attention to this matter in discussing several papers at the Montreal Convention last year, and notes that some reference is made to it in the program for the coming convention at Cleveland.

The cost of industrial water supplies when distributed over the output of a given industry is usually but a small part of the total cost. The increasing difficulty in securing satisfactory supplies

and the inability to purify the polluted supplies may be expected to increase the importance of industrial water supply in the future.

The waters of Western Pennsylvania are naturally low in alkalinity, due to the prevailing geological measures. On the other hand, large areas of the district in question, comprising practically all of Southwestern Pennsylvania, are underlain by the coal measures, at several points of which as many as five different seams are being worked. It is undoubtedly true that the natural alkalinity of the streams would be little affected by the discharge from the mills, and that there would be no apparent improvement in the quality of the river water at this time if such discharges should be discontinued. Furthermore, the mills only pollute the streams with acid during the periods of active operation, while the coal mines produce acid waters constantly, continuing even after abandonment. The large area covered by the workable coal measures makes it practically impossible to secure a water supply beyond the outcrop and any supply secured from within the outcrop, even though the coal may still be undeveloped, is exposed to the same hazards unless the pollution may be restrained by legal means.

The disappearance of acid and decomposable salts between Locks No. 2 on the Allegheny and Monongahela and Lock No. 3 on the Ohio does not necessarily improve the water for industrial purposes, as the neutralization has merely altered the form of the sulphate radical, only a minor portion having been removed. Mr. Young states that "it is regrettable that no simple remedy presents itself." This is certainly true, but in the writer's judgment a much stronger statement is fully warranted—that no remedy presents itself. The water treatment plant of the H. C. Frick Coke Company was described by Mr. L. D. Tracey in the May, 1920, issue of *Mining and Metallurgy* and subsequently discussed by the chief chemist of the Frick Company and by the writer. This plant marks an important step in the right direction, in that it pays its way, but the effluent is not suitable for use in boilers or for many other industrial purposes.

The usual methods of water treatment produce a single precipitation, leaving sodium sulphate in solution, and, in general, increase the total solids, although reducing incrusting solids. The presence of small quantities of sodium sulphate is not necessarily harmful, but if the amount is large it introduces many difficulties. As stated by Mr. Young, it seems probable that all forms in which SO_4 reaches a boiler are harmful. The chemical reactions which occur at high

pressures and temperatures are uncertain, and it seems unnecessary to state that a steam boiler is not a proper place for such experimentation. Barium has been used to a small extent as it has the advantage of removing sulphates and reducing total solids. It has not come into common use for treating boiler water owing to its high cost. For domestic purposes it has the additional disadvantage of the uncertainity as to the conditions under which it is toxic.

Decreasing the total acidity of the rivers by the discharge of waters which have been treated for boiler and cooling purposes is certainly a most extravagant way of producing a desirable result. Possibly the regulating effect of storage reservoirs, as proposed by the Pittsburgh Flood Commission, would produce such an effect at much lower cost.

While it is true that free acid will attack the decomposable or organic matter present in sewage, it is equally true that the sewage could be rendered stable at a lower cost to the public, by the use of sewage treatment plants, rather than as at present by the action of acid mine drainage. The water supply of the City of Altoona (which is not within the district in question) shows free acid and a low bacterial content at all times. Nevertheless it is chlorinated as a further safeguard, and a study is being made in an effort to avoid the use of this polluted water. Practically all of the smaller rivers where coal has been developed are so seriously polluted that no effort is made to use them. At one plant a seriously polluted stream is used in a jet condenser by lining the body with cement, the pump with lead and making other parts of the condenser and pump which come in contact with the water of phosphor bronze. Even under these conditions, certain parts of the condenser must be replaced about every three months. A screen of $\frac{3}{4}$-inch copper plate with holes punched through is destroyed in approximately a year's time. Many of the steel mills are equipped to treat the water used to cool the rolls. It is found that the water changes so rapidly that unless it is treated at all times the roll may be seriously damaged.

The life of boiler tubes for locomotive purposes mentioned is in error, as under the then existing Interstate Commerce Commission regulations tubes could not remain in a boiler for more than three years, although during the war this was increased to four. The period of locomotive boiler wash is also prescribed by Interstate Commerce Commission regulations. Using good waters for boiler feed, there is practically nothing in the boiler to be removed at the

end of the prescribed 28-day period. Using polluted or treated waters, the wash must be made much more frequently. One of the larger railroads in the district removes and renews the water in locomotive boilers at the end of each trip. The most serious difficulty due to using bad water is in the possibility of delays on the road. These are also the most difficult to reduce to cost or loss basis, but they are nevertheless just as real as the more direct costs. On occasions it has been impossible to remove coal from mines promptly owing to damage to locomotive boilers caused by using waters polluted with drainage from the mines producing the coal. It is difficult to calculate the total loss due to using bad water, and the total of $800,000.00 per annum is certainly underestimated.

Reference is made by Mr. Young to the supply of pure water which the Pennsylvania Railroad Company obtains for locomotive use from the mountains to the east. The several water companies which obtain water from that stream have now joined with the Pennsylvania Railroad Company and have entered suits to prevent the destruction of the stream as a water supply by coal mine drainage, as a number of mines have been opened on the watershed within the past few years.

The difference in pollution between the Youghiogheny and Monongahela Rivers may readily be explained by the difference in their drainage areas. The Youghiogheny, being much smaller, naturally shows more serious pollution, as the coal on its watershed has been more extensively developed and the percentage of mine drainage which it carries is greater. The annual report of the City of McKeesport Water Department for 1916–1917 shows that for the period between 1910–1917, the maximum methyl orange acidity of the Youghiogheny River was 390 parts per million, while that of the Monongahela River was 40, and, further, that, while the Youghiogheny is acid in reaction continuously, the Monongahela is usually alkaline. The same report shows that by changing the source of raw water from the Youghiogheny River to the Monongahela River, the cost of chemicals required was reduced 90 per cent. This plant is very successful indeed, but the scale forming content of the effluent water is still so high that large industrial plants find it desirable to treat the same for boiler purposes. This treatment also requires the use of an anti-foam compound.

The City of Pittsburgh procures its water supply from the Allegheny River. The Pennsylvania Department of Health some years

ago made an extensive study of this entire watershed and called attention to the progressive lowering of alkalinity in this river, and the eventual necessity for treating this large supply to remove the industrial pollution as well as for filtering it to improve the sanitary qualities. The annual report of the Bureau of Water of the City of Pittsburgh for 1912 also called attention to that situation. While the city water supply has been acid at the intakes on occasions, this acidity has been of short duration and has been neutralized by the water in the settling basins.

The water situation in the Pittsburgh district is becoming more serious. Stream flows have been unusually favorable during the past few years. The first year of drought during the summer or fall season will undoubtedly produce serious difficulties. The steel hulls of boats and the steel portions of the dams on the rivers in this district are rapidly being attacked by the acid waters. Municipalities are having increased difficulties in furnishing suitable water to their residents. The water required for industrial purposes, as pointed out by Mr. Young, is many times greater in quantity than that required for domestic purposes and the standards are entirely different. With the continued increase in the pollution of streams, pure supplies are becoming more difficult to obtain. Unless methods of industrial purification can be developed, it is difficult to see how additional water supplies for the future growth of this great industrial center will be secured. The problem is of such a serious nature and—the results are so apparent in navigable rivers in various states, that, in the writer's judgment, only the federal government is in a position to cope with the situation. If a careful study of the question should be undertaken at once, with research on a scale comparable with the importance of the problem, it might be possible to have a remedy available by the time the situation becomes acute in other districts, thereby avoiding the problems which today are so serious in the Pittsburgh district.

In conclusion, the writer believes that Mr. Young has contributed a very important paper to the JOURNAL, and recommends that the Association give the subject of industrial water supply serious consideration. If the subject is found to be within the range of its proper acitivity, the conditions should be brought to the attention of the proper agency of the Federal government for remedial action.

CHARLES HAYDOCK.[2]

[2] Engineer, Commercial Trust Building, Philadelphia, Pa.

Acid Pollution of Streams

As a discussion of the paper[1] of Prof. C. M. Young on the acid pollution of the streams of the Pittsburgh Engineer District, I will state that the object of the investigation conducted by the United States Engineers Office was to obtain information bearing on the extent and sources of the acid reaching the rivers and if possible to suggest means to better the conditions complained of by boat men.

Attempts have been made in recent years to have Congress amend the laws for the protection and preservation of the navigable waters of the United States to the end that acid wastes from manufacturing plants, as well as that originating in coal mines, might be controlled, or minimized sufficiently, to reduce materially damage to hulls of steel vessels, steam boilers, valves, lock gates, etc., and incidentally to improve the water for the generation of steam.

It should be understood that the United States exercises no control over waterways save such as are concerned with the *interest of navigation*. With respect to deposits, or refuse, placed in the streams, or on their banks, Section 13, of the River and Harbor Act, approved March 3, 1899, reads, in part, as follows: "That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharge, or deposited either from or out of any ship, barge, or other floating craft of any kind or description whatever, other than that flowing from streets and sewers and passing therefrom in a liquid state into any navigable water in the United States, or into any tributary of any navigable water from which the same shall float, or be washed into such navigable water."

Friends of the proposed amendments entertained the hope that ways might be found by the treatment of acid water to obtain by-products of commerical value, useful in the arts, and valuable as fertilizers, obtaining them without increasing the cost, or difficulties of coal mining or seriously inconveniencing manufacturers using acids.

During the course of the investigation more than 260 persons, having more or less knowledge of the subject, were interviewed, included among them being 40 managers of manufacturing industries, 55 mechanical, civil, metallurgical and consulting engineers, 32 chemists, 15 coal operators, 22 Pennsylvania State mine inspectors, 6 city and state officials, 6 physicians expert in bacteriological study, and a number of plumbers, tanners, launderers, railway

officials and round house employees, boiler makers, etc. Especially valuable was the aid given, and facilities furnished for tests, by the United States Bureau of Mines. Data were furnished also by the U. S. Marine Hospital Service which happened, at the same time, to be investigating river conditions along the Ohio at many points for 400 miles below Pittsburgh. The data thus secured along with that obtained by personal examinations of the office assistants, covered 960 pages of typewritten matter. Owing to conditions resulting chiefly from the great war, nothing has been done officially with the data. In fact the work had to be stopped by the press of other duties before any definite recommendations could be made.

It so happens that very low water conditions have not been experienced for several years past, and accordingly there has been more than the usual summer and fall dilution of acids reaching the main streams. It is doubtless the case, however, that the acids from mines is constantly increasing, corresponding with the growth of the coal trade, but at present it is the case that spent acids from steel works, etc., is below the average due to so many plants being either closed, or operated for shorter daily, or weekly, periods.

The Engineer Department of the Army is, of course, interested in the matter of the purification of water supply. It is not only the Pittsburgh region, but coal producing areas in eastern Pennsylvania, Ohio, West Virginia, Indiana, Illinois and Kentucky, which add enormously to the total acid pollution of our rivers. The grand aggregate extends into millions of tons of acid, or acid salts, or bases, annually reaching the streams. Vast as is the annual waste of chemical materials from mines and mills estimated to be worth $20 per ton, it is not greater than the areas surrounding the mines, in need of the fertilizers said acid might possibly be made to produce. The subject is one that should be studied by the agricultural chemists, as well as by the experts on public water supplies.

THOS. P. ROBERTS.[3]

CONTROL OF OPERATION OF FILTER PLANT BY H-ION CONCENTRATION[4]

It is altogether practical to put a set of "color standards" for the determination of hydrogen ion concentration into the hands of an untrained man and get valuable results. This conclusion is

[3] Assistant Engineer, U. S. Engineer Office, Pittsburgh, Pa.

[4] JOURNAL, May, 1921, page 239.

evident from the experience of the past few months, during which time an untrained man has, with only the briefest explanation of the use of such a set, made daily determination of the *acid index* of a water supply. These tests have been extremely useful in controlling the application of chemicals in a small filter plant where corrosion troubles have been acute for several years.

W. F. MONFORT.[5]

[5]Consulting Chemist, 506 N. Vandeventer Avenue, St. Louis, Mo.

SOCIETY AFFAIRS

THE ANNUAL CONVENTION

The Forty-first Annual Convention was formally opened on June 7, 1921 at the Hollenden Hotel, Cleveland, Ohio. On June 6, however, the executive committee had a preliminary meeting, while other standing and special committees also transacted their business. On the same day the Council on Standardization, with George A. Fuller presiding, conducted an informal discussion of the proposed scope and policies of the Council.

On the evening of June 6, a dance and reception were held at the Hollenden Hotel. Director Thomas S. Farrell of the Cleveland Department of Public Works, presented the "key of Cleveland" to President Beekman C. Little, on behalf of Mayor Fitzgerald of the city of Cleveland, who was unable to be present. President Little responded with a brief speech of acceptance.

Morning Session, June 7. Presiding officer, President Little.

After the official opening of the convention, the result of the election of officers was announced. President, Dr. Edward Bartow; vice-president, W. S. Cramer; treasurer, William W. Brush; trustee, District 1, George C. Gensheimer; trustee, District 3, J. Chris Jensen.

The chairman appointed a committee on resolutions consisting of Carleton E. Davis and John M. Goodell.

The following papers illustrated by lantern slides were presented and discussion was reserved until they had all been given:

"Construction Program of the Cleveland Water Works," A. V. Ruggles.

"A Reservoir Vs. Additional Pumping Equipment for Supplying Peak Demands,"[1] L. A. Quayle.

"Cleveland's Water System in Story and Picture," G. E. Flower.

"A Sanitary Survey of Lake Erie Opposite Cleveland with Reference to the Location of New Water Works Intakes," J. W. Ellms.

"Investigation for Causes of Obnoxious Tastes and Odors Sometimes Occurring in the Cleveland Water Supply," J. W. Ellms and W. C. Lawrence.

[1] See page 463 of this JOURNAL.

"The Rate of Solution of Sulphate of Alumina, with Reference to the Design of Solution Tanks,"[2] J. W. Ellms, A. G. Levy, and L. A. Marshall.

The above papers were discussed by Messrs. Habermeyer, C. Arthur Brown, John N. Chester, A. G. Levy, C. R. McFarland, J. W. Ellms, and L. A. Quayle.

Owing to lack of time, the following papers were read by title only:

"Division Pumping Station, a Description of the Station and its Operation,"[3] J. N. H. Christman.

"Fairmont Municipal Heating Plant, a Description of the Largest Municipal Heating Plant and its Operation," H. W. Kaiser.

In this morning session, George E. Cripps introduced a resolution expressing the regret of the convention that Charles R. Wood was compelled to be absent because of an injury and offering to him wishes for a speedy recovery. The Secretary was instructed to forward a copy of the resolution to Mr. Wood.

Afternoon Session, June 7. Presiding officer, President Little.

The following papers were presented:

"The Waste of Water in Detroit," George H. Fenkell; discussion by William W. Brush, John N. Chester, H. P. Bohmann, A. P. Claflin, and the author.

"The Results of Cleaning Water Mains at Kansas City,"[4] C. S. Foreman; discussion by W. W. Brush, H. P. Bohmann, Philip Carlin, J. N. Chester, and the author.

"Water Rates," Nicholas S. Hill, Jr.

"Water Rates."[5] E. E. Bankson, D. E. Davis, and C. A. Finley. The last two papers were discussed jointly by J. N. Chester, Allen Hazen, Philip Burgess, W. W. Brush, J. W. Ledoux, H. C. Crowell, and the authors.

The Chair announced the election of the following members of the Nominating Committee: District 1, Patrick Gear; District 2, J. Walter Ackerman; District 3, William R. Edwards; District 4, H. E. Keeler; District 5, E. B. Black; District 6, F. D. H. Lawlor.

Evening Session, June 7. Presiding officer, President Little.

The program for this session was under the auspices of the Water Works Manufacturers' Association. The papers presented were:

[2] See JOURNAL, July, 1921, page 426.
[3] See JOURNAL, July, 1921, page 433.
[4] See JOURNAL, July, 1921, page 369.
[5] See page 497 of this JOURNAL.

"Water Supply from the Supply Man's Viewpoint," Charles H. Ade.

"The Electrical Control of Valves," Peter Payne Dean, with lantern slides; discussion by W. W. Brush and J. M. Diven.

"Experience in the Development of Oil Engines."[6] F. B. Leopold; discussion by N. M. R. Wilson, J. W. Ackerman and R. B. Hammond.

"Standardization of Meters," R. K. Blanchard; discussion by Beekman C. Little and E. M. Nichols.

Morning session, June 8. Presiding officer, President Little.

The Annual Presidential Address was read by President Little. The following papers were then presented:

"The Romance of Water Storage."[7] George A. Johnson; discussion by B. C. Little, R. S. Weston, A. H. Jewell, Richard Messer, R. B. Morse, and the author.

The report of the Finance Committee[8] was presented by Col. Geo. A. Johnson, chairman, and adopted by a formal vote.

"The Water Works of Erie, Pa.," John N. Chester, with lantern slides; discussion by M. N. Baker, G. C. Gensheimer, Allen Hazen, and the author.

"Overcoming difficulties with Animalcules at the Dallas Filters,"[9] Helman Rosenthal.

Following these papers, further committee reports were read. The report of the Council on Standardization[10] was presented by the chairman, George W. Fuller. The report was adopted.

In the absence of the chairman of the committee on Standard Form of Contract, J. M. Goodell, for the chairman, requested that the committee be continued for another year.

The Committee on Private Fire Protection Service reported that it was preparing a final report for the next convention. The committee was continued.

F. C. Jordan, chairman, made no formal report for the Membership Committee, but urged increased efforts for enlarging the membership list of the Association. The committee was continued.

The Standard Brass Fittings Committee reported progress and was continued.

[6] See JOURNAL, July, 1921, page 412.
[7] See JOURNAL, July, 1921, page 291.
[8] See JOURNAL, July, 1921, page 448.
[9] See page 530 of this JOURNAL.
[10] See page 535 of this JOURNAL.

The report of the Committee on Revision of Standard Specifications for Cast Iron Pipe and Specials was read by its chairman, F. A. Barbour. This report was discussed by J. N. Chester, Allen Hazen, J. M. Diven, H. F. Dunham, and F. A. Barbour, after which it was accepted. The committee was continued.

The report of the American Committee on Electrolysis, according to N. S. Hill, one of the Association's representatives, is being prepared for publication.

Secretary Diven announced that the referendum vote on the amendment to the constitution, recommended by the executive committee, showed about ten to one in favor of an increase in annual dues from five to seven dollars for active, five to ten dollars for corporate, and ten to fifteen dollars for associate members. In addition the constitution was so amended as to have the secretary send notice of dues one month, instead of fifteen days, before the close of the year.

The amendment providing for a vote for officers by the convention, instead of by letter ballot, when only one set of nominations was in the field, was adopted.

Another amendment providing funds for the national sections was presented and adopted.

Afternoon session, June 8. Presiding office, Vice President Bartow.

The following papers were presented and discussed jointly:

"The Small Plant Operator as Scientist,"[11] Abel Wolman.

"The Loading of Filter Plants," H. W. Streeter.

"Tastes and Odors with Chlorination," W. A. Sperry.

"The Quality of Water at Different Points on a Water System,"[12] S. T. Powell; in the absence of the author, the paper was presented in abstract by Abel Wolman.

"State vs. Local Viewpoint on Filter Plant Control,"[13] R. B. Morse.

"The Education and Training of Water Plant Operators," Lewis O. Bernhagen.

"Licensing Filter Plant Operators in New Jersey,"[14] Charles H. Capen, Jr.

[11] See JOURNAL, July 1921, page 359.
[12] See page 522 of this JOURNAL.
[13] See JOURNAL, July, 1921, page 356.
[14] See JOURNAL, July, 1921, page 362.

The discussion following these papers was spirited and was taken part in by N. J. Howard, R. B. Morse, C. A. Brown, Paul Hansen, W. J. Orchard, D. R. Gwinn, F. W. Green, F. H. Waring, H. E. Jordan, A. U. Sanderson, Allen Hazen, and Abel Wolman.

Morning session, June 9. Presiding officer, T. A. Leisen.

The report of the Committee on Standard Specifications for Water Meters,[15] of which C. M. Saville is chairman, was received and adopted.

This report was followed by a paper on: "A Method of Determining by a Single Flow Test of a Meter its Capacity at All Pressure Losses," F. B. Nelson, with lantern slides; discussion by W. W. Brush, R. K. Blanchard, E. S. Cole, and the author.

The following papers were read by title, in the absence of the authors:

"Use of Dynamite in Breaking Out Old Water Mains," Alvin Bugbee.

"Water Works Publicity," Scotland G. Highland.

Since time was available in this session, water works topics and questions were taken up.

The question, "Experience with Double Check Valves between Public Water Supplies and Polluted Private Fire Protection Supplies," was discussed by J. W. Ackerman, D. R. Gwinn, E. E. Davis, W. R. Young, Patrick Gear, and C. M. Crowley.

This discussion was followed by the presentation of the paper:

"Tapping Large Steel Mains Under Pressure," D. F. O'Brien, discussion by Philip Carlin and the author.

The question, "Extension of Water Mains," was discussed by D. R. Gwinn and W. W. Brush.

Dr. Edward Bartow then reported that the new Executive Committee had met and had reappointed J. M. Diven as secretary for the following year. The appointment of Abel Wolman was also announced as editor of the JOURNAL of the Association, to succeed J. M. Goodell, resigned. The following resolution was offered by the Executive Committee and was unanimously adopted by the convention:

The Executive Committee appreciates the services of Mr. J. M. Goodell as Editor of the publications of the Society during the past four years, and

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[15] See JOURNAL, May, 1921, page 273.

in acceding to his request that he be relieved from further service as Editor, recommends that the Association extend to Mr. Goodell a vote of thanks for the services he has rendered to this Association.

A similar vote of thanks was tendered to G. A. Johnson, the retiring chairman of the Finance Committee.

The Committee on Resolutions submitted a resolution thanking the Entertainment Committee and their associates in Cleveland for providing such excellent entertainment for members and guests of the Association during their visit to the city.

The Nominating Committee gave as their nominations for officers of next year the following list:

President, W. S. Cramer; Vice-President, George W. Fuller; Treasurer, W. W. Brush; Trustee, First District, G. W. Batchelder; Trustee, Fourth District, J. W. Ellms.

The vote for the city in which to hold the next convention resulted in the selection of Philadelphia.

Afternoon session, June 9. Presiding officer, D. R. Gwinn.

The following papers were presented:

"Mechanical Aids in Distribution Work," W. Montgomery Mitchell, with lantern slides; discussion by T. A. Leisen, H. C. Crawford, and the author.

"Ownership and Operation of Trench Excavators and other Mechanical Equipment by the Water Department of Baltimore," V. Bernard Siems, with lantern slides; discussion by W. Luscombe, T. A. Leisen and the author.

The paper on "Construction and Maintenance of a 6-inch Galvanized Wrought Iron Submarine Pipe Line" by James W. Graham was read by title.

Morning session, June 10. Presiding officer, President Little.

No definite program was planned for this morning. The following topics were discussed:

"Experience with Double Check Valves," discussed by W. A. McCaffrey and J. M. Diven.

"Failure of Cast Iron Pipe and the Causes," discussed in writing by Frank McInnes and on floor by J. M. Diven and B. C. Little.

"How to Obtain the Good Will of the Consumer," discussed by D. R. Gwinn, J. M. Diven, C. A. Brown, H. P. Bohmann, P. M. Wilson, E. E. Davis, F. C. Amsbury, C. R. Claflin, and H. C. Crawford.

A motion by P. M. Wilson that a committee be appointed by the Association to collect data dealing with methods of obtaining the good will of consumers was carried.

"Experience in Water Works Operation under Public Utility Regulations," discussed by E. B. Whitman, C. D. Vail and J. W. Ackerman.

"Services," discussed by J. W. Ackerman, G. C. Gensheimer, A. P. Folwell, A. J. Feeney, F. C. Amsbury, B. C. Little, S. Scarth, and J. F. Willett.

Afternoon session, June 10. Presiding officer, President Bartow.

The topical discussion was continued from the morning session.

"Water Bills," discussed by J. M. Diven, W. G. Patterson, H. F. Blomquist, and F. C. Amsbury.

"Knocking or Hammering in Water Mains," discussed by W. G. Patterson, G. C. Gensheimer, and H. F. Dunham.

These discussions were followed by a paper with lantern slides, on material handling equipment by G. R. Bascom. Other moving picture films were later shown which dealt with problems such as the manufacture of cast iron pipe, of trenching machines, and of valves.

At the convention there were approximately 410 active members, over 300 associates, and about 400 guests. On the evening of June 8, a smoker, and of June 9 a boat ride on the Lake were given. Excursions to various points of the city, theatre and card parties were provided for the ladies during the convention.

Chemical and Bacteriological Section, June 9. Presiding officer, J. J. Hinman, Jr.

The following papers were presented:

"Coagulation and Sedimentation with Chemicals," J. W. Ellms.

"Some Notes on Colloidal Chemistry as Applied to Water Filtration," Milton F. Stein.

"Application of Colloid Chemistry to the Study of Filtration," Malcolm Pirnie.

"Turbidimetry of Water," P. V. Wells.

"The Physical Chemistry of Iron Removal from Water," Robert Spurr Weston.

"Application of Colloid Chemistry to the Filter-Pressing of Sewage Sludge,"[16] John Arthur Wilson, Wm. R. Copeland, Henry Mills Heisig.

[16] See page 486 of this JOURNAL.

"Colloid Chemistry of Tank Treatment of Sewage," Langdon Pearse and F. W. Mohlman.

"Pollution of Streams by Waste from a Hydrogen Generating Plant," Edward Bartow and A. S. Behrman.

"The Reactions of Culture Media," George C. Bunker. Read by title.

The officers of the Section elected for the following year are: chairman, Allen Hazen; secretary, J. J. Hinman, Jr.; Executive Committee, Milton F. Stein, William Mansfield Clark, Lynn H. Enslow, Norman J. Howard, A. M. Buswell, Harry E. Jordan, W. C. Lawrence, F. H. Waring, and W. D. Hatfield.

The attendance at the sessions of the Section was about 150. The meetings were marked by active participation by a number of members in the discussions of the various papers.